LET'S CLEAR THE AIR

Did you know -- WE COULD HAVE BEEN USING ETHANOL AS "THE" AUTOMOBILE TRANSPORTATION FUEL TODAY?

Ethanol has been known as a fuel for centuries. Indeed, when Henry Ford designed the Model T, it was his expectation that ethanol, made from renewable biological materials, would be a major automobile fuel. However, gasoline emerged as the dominant transportation fuel in the early twentieth century, because of the ease of operation of gasoline engines with the materials then available for engine construction, and a growing supply of petroleum from oil field discoveries.

But gasoline had many disadvantages as an automotive source. The "new" fuel had a lower octane rating than ethanol, was much more toxic (particularly when blended with tetra-ethyl lead and other compounds to enhance octane), was generally more dangerous, and contained threatening air pollutants. Petroleum was more likely to explode and burn accidentally; gum would form on storage surfaces; and carbon deposits would form in combustion chambers of engines. Pipelines were needed for distribution from "area found" to "area needed". Petroleum was much more physically and chemically diverse than ethanol, thereby necessitating complex refining procedures to ensure the manufacture of a consistent "gasoline" product.

Because of its lower octane rating and higher ignition temperature relative to ethanol, the use of gasoline meant the use of lower compression engines and larger cooling systems.

Diesel engine technology, which developed after the early emergence of gasoline as the dominant transportation fuel, also resulted in the generation of large quantities of pollutants.

However, despite these environmental flaws, fuels made from petroleum have dominated automobile transportation for the past three-quarters of a century. There are two key reasons: One, petroleum, despite its fossil origin, has been treated as if present in endless supply. And two, cost per kilometre of travel has been virtually the sole selection criteria.

Environmental concerns have been largely ignored.

PROGRAM

LET'S CLEAR THE AIR

Seminar on how automobile fuel affects your life

Wednesday, October 18, 1989
Metro Toronto Convention Centre
Press Conference Room

Chairman — Terry Daynard, Canadian Renewable Fuels Association	
Introduction — Terry Daynard	10:00 a.m.
How renewable fuels contribute to clean air	10:15 a.m.
Eric Vaughn, Renewable Fuels Association Washington, DC	
Vehicle research for future fuels	11:00 a.m.
Roberta Nichols, Ford Motor Company Dearborn, MI	
Discussion	11:45 a.m.

LUNCH with speaker — Room 206F
12:00 noon

Two years with the Colorado oxygenated fuels program
Tony Massaro, City of Denver
Denver, CO

Press Conference Room

Chairman — Beth Candlish, Biomass Energy Institute

Effects on the environment of the fuels we are using **Colin Isaacs, Environmentalist** **Toronto, ON**	2:00 p.m.
Canadian experience with renewable fuels **Art Meyer, Mohawk Oil Co.** **Burnaby, BC**	2:45 p.m.
Discussion and closing remarks — Beth Candlish	**3:30 p.m.**

Beth Candlish is Executive Director of the Biomass Energy Institute, Winnipeg, Manitoba. Beth graduated from McGill University with a B.Sc. in agriculture in 1952, obtained her M.Sc. in Plant Science from the University of Manitoba in 1968, and Ph.D. in Animal Nutrition and Plant Biochemistry in 1970. Beth has spent most of her life in the agriculture industry, joining the Biomass Energy Institute three years ago.

Colin Isaacs is an environmental consultant from Stoney Creek, Ontario. Until June 1989, he was Executive Director of The Pollution Probe Foundation. Colin has degrees in chemistry from Imperial College, University of London, and carried out graduate research at the University of Western Ontario. He was a member of the Ontario Legislature from 1979 to 1981, and is currently a member of the Ontario Recycling Advisory Committee and the Ontario Round Table on Environment and Economy.

Arthur E. Meyer, P. Eng., is Vice-President and Director, Mohawk Oil Co. Ltd., Burnaby, B.C. Art graduated from the University of Saskatchewan in 1949 with a M.Sc. Mechanical Engineering. He was employed by Royalite Oil Co. Ltd. until 1963 in refining and marketing positions. From 1964 to 1977, Art operated as Managing Partner for Associated Engineering Services Ltd. in Calgary and Edmonton. From 1978 to 1985, he was President of RDC Research Development and Consulting Ltd. investigating alternate fuel opportunities for Mohawk.

Biographies

Terry Daynard is Executive Vice-President, Ontario Corn Producers' Association, Guelph, Ontario, and President of the Canadian Renewable Fuels Association. Terry graduated from the University of Guelph with a Ph.D. in agriculture in 1968 and did a post-doctorate at the University of Kentucky. Since 1969, he has been a faculty member of the Department of Crop Science at the University of Guelph, and since 1972 has owned and operated a cash crop farm in Guelph township.

Bob Dineen replaced Eric Vaughn, and is the Legislative Director for the Renewable Fuels Association, Washington, D.C. Bob is originally from Boston. He has spent 12 years in Washington, dealing with various organizations and Congress. The last two and a half years he has been with the Renewable Fuels Association.

Roberta Nichols is Manager of the Alternate Fuels Department, Automotive Emissions and Fuel Economy Office for Ford Motor Company, Dearborn, Michigan. She has been in charge of the demonstration fleets for methanol, natural gas, and production for Ford Brazil ethanol and propane. Roberta graduated from UCLA with a B.Sc. in physics, from USC with a M.Sc. in Environmental Engineering, and a Ph.D. in Engineering. She is presently working on the flexible fuel vehicle.

Tony Massaro is Director of Environmental Affairs for the City and County of Denver, Colorado. Tony attended Colorado State University, majoring in Political Science. Since 1983, he has been responsible for the development of environmental policy for the city. Tony has served on Governor Lamm's Oxygenated Fuels Task Force and Governor Romer's Diesel Task Force.

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President/Chief Executive Officer

Presentation of

Eric Vaughn
President & Chief Executive Officer
Renewable Fuels Association

Before the

"Let's Clear the Air Conference"

sponsored by
The Canadian Renewable Fuels Association
and
The Biomass Energy Institute

Toronto, Canada
October 18, 1989

On behalf of the members of the Renewable Fuels Association, the national trade association for the United States ethanol industry, I want to thank the members of the Canadian Renewable Fuels Association and the Biomass Energy Institute for inviting me to address this exciting Conference on the role of alternative fuels, especially ethanol and ETBE, in meeting critical environmental objectives, such as reducing carbon monoxide, carbon dioxide and ozone pollution in our major metropolitan areas.

INTRODUCTION

The United States fuel ethanol industry has a current operational production capacity of over 1 billion gallons per year. More than 60 ethanol manufacturing facilities located in 22 states are operating today. Domestic ethanol producers have invested over $2.5 billion in private sector resources to construct modern and efficient ethanol production facilities.

In 1988 alone, 850 million gallons of ethanol were produced from 340 million bushels of surplus grain. As a direct result of ethanol production, it is estimated that farm income in 1988 increased $750 million, federal farm program costs were reduced by nearly $600 million, and crude oil imports fell by 40 million barrels.

Fuel grade ethanol became commercially available in the U.S. in the late 1970's in response to a national policy to promote the development of domestically produced alternative energy sources to reduce our dependence on foreign oil.

Today, ethanol/gasoline blend sales represent over 8 percent of all motor fuels sold in the U.S. While ethanol was originally used as a gasoline extender, capable of stretching tight gasoline supplies, ethanol is currently marketed as a high quality octane booster capable of improving automobile performance by adding 3 octane points with every 10% ethanol blend. In the future, we expect ethanol may be marketed as an ether based oxygenate - ethyl tertiary butyl ether (ETBE). ETBE has the potential of opening major new markets for ethanol because it can be blended at refineries and shipped through common carrier pipelines. In addition, ETBE can actually reduce the volatility of the base gasolines with which it is blended. While ETBE is not yet commercially available, it promises to be a valuable supplemental market to 10% ethanol blends and a natural competitor to the only ether based oxygenate available today-methyl tertiary butyl ether (MTBE).

Over the past ten years, ethanol blended fuels have won wide consumer acceptance as a high octane, high performance gasoline additive. In fact, since 1980, over 700 billion miles have been driven on ethanol blended fuels. One indication of the continuing and growing demand for ethanol blends are the market penetration levels in states where ethanol is sold. In 1988, 10 states recorded market penetration levels for ethanol that range from 16% to 39%. States with the highest market penetration levels are as follows: Kentucky, Iowa, Nebraska, Illinois, and Indiana.

Furthermore, ethanol blends are approved under the warranties of <u>all</u> 19 domestic and foreign automobile manufacturers marketing vehicles in the U.S. In fact, earlier this year, Roger B. Smith, Chairman of General Motors, announced that beginning with 1990 model cars and trucks, GM would begin <u>recommending</u> the use of oxygenated fuels. In making the announcement, Smith stated, "The advantage here is that the oxygen from the ether or alcohol portion of these special fuel blends can act to make the engine's air-to-fuel ratio leaner, (and) the result is less carbon monoxide." The new GM warranty language reads:

<u>Gasolines for Cleaner Air</u>

The fuel that you use can contribute to cleaner air. General Motors recommends that you use only gasolines treated with detergent additives that prevent deposit formation in your engine. These gasolines will help keep your engine in tune and your emission control system working properly.

The use of oxygenated materials in gasoline can also contribute to cleaner air, especially in those parts of the country where carbon monoxide and ozone levels are high. Where available, General Motors recommends use of oxygenated fuels such as MTBE and ethanol in gasoline.

The Air Quality Benefits of Ethanol and ETBE:

In recent years, the remarkable growth of the ethanol industry has been directly related to its increasing use as a weapon against air pollution for the nation's 90 carbon monoxide and ozone non-attainment cities. Many state and local governments are beginning to recognize the enormous environmental benefits of ethanol and are looking at programs to increase the use of ethanol blends as a means of reducing dangerous levels of carbon monoxide and ozone. One such program in Colorado has been highly successful in reducing CO in Denver's Front Range, previously the worst area for CO in the country. I understand Toronto suffers from pollution levels as serious as those found in the Denver, Colorado area. The success of the Denver alternative fuels program has prompted other states, such as Arizona, New Mexico and Nevada, to adopt oxygenated fuel programs in their State Implementation plans to come into compliance with EPA standards.

Ethanol and ETBE have a number of air quality and public policy benefits which must be considered in the context of Clean Air Act reauthorization. First, because the oxygen content of an ethanol blend is almost twice that of other oxygenated fuels, its ability to reduce carbon monoxide (CO) levels is greater than any alternative oxygenated fuel. The use of ethanol blends will reduce motor vehicle emissions of CO by 25 - 30 percent. Second, recent analysis indicates that ethanol blended fuels can reduce the formation of urban ozone, a fact recognized by the U.S. Environmental Protection Agency as early as January, 1988. Finally, ethanol is an effective and safe replacement for dangerous aromatic octane enhancers in gasolines today.

Ethanol As A Carbon Monoxide Emissions Control Strategy

The addition of molecular oxygen contained in ethyl alcohol (C_2H_5OH) causes more air to be available in the fuel, thus the air/fuel ratio in the internal combustion engine is altered to the extent that the engine is more efficient in converting toxic carbon monoxide to non-toxic carbon dioxide.

Since 1987, the U.S. Environmental Protection Agency (EPA) has recognized that the use of ethanol blends can reduce fleetwide carbon monoxide exhaust emissions by 25 percent. EPA published a technical document to be used by the States in revising their SIP's in the post-1987 era, "Guidance on

Estimating Motor Vehicle Emissions Reductions From the Use of Alternative Fuels and Fuel Blends." This document lists the following exhaust emissions reductions that can be achieved by using ethanol blends:

non-catalyst (pre-1974 vehicles)	-22.8 percent
open-loop catalyst (1975-1981 vehicles)	-33.4 percent
closed-loop catalyst (post-1981 vehicles)	-17.2 percent

Carbon monoxide is an intermediary component of combustion. Normally it proceeds to be completely oxidized into carbon dioxide (CO2) during the later stages of combustion. But it can remain a pollutant if (1) the combustion gas temperatures are low; (2) if the duration of time it spends in the combustion process is short; and (3) if there is a lack of oxidants; i.e., oxygen-containing molecules. Increasing the air/fuel ratio present during combustion results in more oxidants being present and higher gas temperatures both of which increase the efficiency of the oxidation of CO into CO2.

The higher the percentage of oxygen by weight in the fuel, the "leaner" the effective fuel-to-air ratio will be; that is, more oxygen is available to enhance the combustion process. As the fuel-to-air ratio becomes leaner, CO emissions are reduced. "Oxygenated" fuels produce a reduction in CO emissions directly related to the leaning effect they have on a vehicle's engine. The percentage of oxygen by weight in the automobile's final fuel determines the amount of CO emissions reduction. Hence, there is no question that ethanol blends substantially reduce CO emissions. This occurs because of the high oxygen content of ethanol. The oxygen content of gasohol is 3.5 percent by weight.

Indeed, to combat its significant CO nonattainment status, the State of Colorado, after several years of exhaustive analysis, promulgated a regulation which requires that only oxygenated gasolines be sold during the winter months along the Colorado Front Range.

The CO emissions reduction capability of oxygenates was corroborated in EPA testimony on June 17, 1987, before the House Subcommittee on Energy and Power, when the director of EPA's Office of Mobile sources stated that:

> "Based on the types of vehicles in the in-use fleet today, our analysis indicates that the use of (oxygenates) would reduce motor vehicle emissions of CO by approximately 22 percent."

A tremendous amount of research to document the impact which oxygenated fuels have on CO emissions reductions is generally available.

Given the very few control options available for CO reduction it appears both reasonable and necessary that all CO nonattainment areas be required to either implement an oxygenated fuels program, or show why comparable emissions reduction will be obtained in the absence of such an oxygenated fuels program.

Ethanol, ETBE and Ozone Pollution Levels:

Ozone pollution continues to be a major concern for large urban areas throughout the United States. A recent analysis performed by SAI conclusively documents that reductions in carbon monoxide caused by ethanol blends in most instances completely offsets any increase in ozone formation attributable to the increased volatility of ethanol blends, and, in fact, at RVP's of 9.0 psi and lower, ethanol blends slightly reduce ozone formation.

Based on their review of SAI's analysis, EPA agreed that reductions in carbon monoxide should be considered with regard to ozone abatement efforts. In a January 1988 document EPA stated:

> "Areas receiving ozone SIP calls and considering adoption of an alternative fuels program should account for its impact on both hydrocarbon and CO emission inventories, since both are inputs to the latest model for predicting future ozone attainment. Directionally, CO emission reductions from alternative fuels will assist in attaining the ozone NAAOS, but the strength of this effect has not yet been documented for the range of local conditions which affect ozone formation." (Guidance on Estimating Motor Vehicle Emission Reductions From the Use of Alternative Fuels and Fuel Blends, January 1988, at page 1) (emphasis added)

In order to further measure "the strength of this effect," EPA's Office of Policy, Planning and Evaluation (OPPE) contracted with Systems Applications, Inc., to perform more rigorous ozone modeling (using the Urban Airshed Model) to more fully ascertain the impact on ozone formation attributable to the use of ethanol blends. The initial results of this study are contained in the May 1989 report, "A Low-Cost Application of the Urban Airshed Model to the New York Metropolitan Area and the City of St. Louis." Although EPA has released this report, it has not been widely disseminated, and, quite frankly, I believe its conclusions have not received the attention due them.

In the computer modeling approach utilized in these studies, the Urban Airshed Model is employed in such a manner so as to take into account time-dependent chemistry associated with

hydrocarbon emissions. This is a very important factor, given that many critics of ethanol blends contend that emissions from ethanol blend-fueled vehicles, while not as immediately photoreactive as gasoline-fueled vehicle emissions, form more ozone over time. The report indicated that this is not the case.

Of the various emissions inventories modeled in this study, included is a 1995 modeling scenario for New York City with 100-percent market penetration of a 10-percent ethanol blend with a 10.0 psi RVP (9.0 psi RVP base fuel, 1.0 psi RVP increase attributed to ethanol); and a 1995 modeling scenario for St. Louis with a 50-percent market penetration of a 10-percent ethanol blend with a 9.8 psi RVP (8.8 psi RVP base fuel, 1.0 psi RVP increase attributed to ethanol). Both modeling scenarios took running losses into account.

For the New York modeling scenario, the report states that, "There is a very slight increase in the maximum daily ozone concentrations, with a maximum increase of less than 1 part per billion... Examination of the difference in hourly ozone concentrations between the ethanol-blend scenario and the low-RVP scenario ... reveals that the effects of ethanol blends on hourly ozone concentrations are very small, with ozone increases or decreases always less than 1 part per billion."

For the St. Louis modeling scenario, the report states that, "the use of a 50-percent market penetration of a 10-percent ethanol-blended fuel with the 1.0 psi exemption results in no increase in the highest ozone concentrations and a slight increase in the maximum daily ozone concentration."

I believe these conclusions, based on the very best technical data base and computer modeling available in the country, are of significant importance to the ongoing debate on the impact of ethanol blends on ozone formation. I believe the results of this exhaustive and thorough study should put to rest, once and for all, the assertion that ethanol blends either now contribute to the ozone problem experienced in metropolitan ares, or would contribute to increasing ozone formation in those areas in which they gain an increased share of the motor fuel market. The plain and simple truth is --- ethanol blends don't contribute to the ozone problem.

These up-to-the-minute results, obtained by the use of state-of-the-art ozone computer modeling, should provide the Committee with further assurance that providing a volatility tolerance for ethanol blends continues to be the appropriate choice in the gasoline volatility section of the Committee's Clean Air Act legislation.

Impact of Lead-Phasedown and Aromatic Content Increase:

Gasoline, today, is a complex mixture of over 200 hydrocarbons. The hydrocarbon composition -- or octane level -- of fuel will determine the propensity of a gasoline to resist "knocking". The higher the octane number, the lesser the tendency of the gasoline to "knock". Over the years, as increased performance has been demanded from automobile engines, greater compression ratios in an engine's cylinders has been necessary, requiring higher and higher gasoline octane levels.

In the 1920's research determined that the octane level of fuel could be increased by the addition of tetraethyl lead. Research studies in the 1970's, however, discovered potential health problems associated with the use of lead in gasoline and on December 6, 1973, the U.S. EPA mandated reductions in the lead content of gasoline beginning January 1, 1975.

One result of the lead-phasedown program has been an increase in the aromatic content of gasoline as a means of replacing the lost octane value previously represented by tetraethyl lead. The aromatic fraction of gasoline has increased an estimated 50% in the last 8 years and EPA documents suggest that by the 1990's it is expected to double from pre-lead phasedown levels.

Moreover, the use of aromatics in gasoline will continue to increase as a result of EPA's fuel volatility standards. This increase in aromatic levels has raised serious concerns about the health and environmental implications of such components when emitted into the air. As more and more scientific information becomes available, the significant health risks associated with aromatic emissions becomes clear. Finally, the increasing percentage in gasoline of highly photoreactive compounds will continue to exacerbate the problem of ozone formation.

Therefore, it would appear that reductions in the aromatic fraction of current gasoline composition would have the beneficial result of not only reducing health risk to the public associated with these compounds, but if less photochemical reactive compounds were utilized in gasoline in their place, it would also assist in the reduction of ozone formation.

The three largest aromatic hydrocarbon components of gasoline currently are: benzene, toluene, and the mixed xylenes, known collectively as "BTX".

BENZENE: It is the basic aromatic in the BTX group. Highly valued as a chemical feedstock. It is estimated that the proportion of benzene in the domestic gasoline pool has increased by at least 50 percent since initiation of lead phasedown, and in fact, the liquid benzene level in gasoline has

more than likely doubled in the past 15 years. It should also be noted that the upper range of liquid benzene content in gasoline is approaching 5 percent in summertime usage.

Benzene is a known carcinogen. The Senate Environment and Public Works Committee report on the Clean Air Act Standards Attainment Act of 1987 noted a study in Los Angeles that "as many as 222 cancers per year in that community could be attributed to toxic air pollutants, principally benzene emitted from gasoline supplies". Also, in a series of toxicological studies the effects of exposure to this hydrocarbon was revealed. For instance, in a recent report released by California's South Coast Air Quality Management District, and funded by the U.S. EPA, researchers found that benzene posed the greatest health risk of all 16 air toxins studied. Study authors also concluded that there is a one in 10,000 chance of getting cancer from benzene exposure, and that 15 percent of those cases would be due to exposure during commuting to and from work.

TOLUENE: At significant exposure levels, toluene can produce impaired human motor functions and distortion of thought processes. It is the most common hydrocarbon octane enhancer purchased by refineries for use in increasing octane. Almost two-thirds of the airborne toluene emissions in 1978 were attributable to gasoline sources: gasoline refueling, automobile evaporative emissions, and automobile exhaust emissions. Consistent with the assumption applicable to populations at risk for exposure to airborne benzene emissions, it can be assumed that urban populations are exposed to larger amounts of airborne toluene from gasoline refueling and automotive emissions than non-urban populations, and sub-populations in close proximity to areas of congested traffic, service stations, and petroleum are at greatest risk.

As is the case with benzene, toluene levels in the domestic gasoline pool since lead phasedown have increased by at least 50 percent, and perhaps substantially more. The amount of isolated toluene used for octane enhancement was estimated at 290-300 million gallons in 1986, up 90-100 million gallons over 1985, accounting for 33 percent of total isolated toluene supply. Toluene ranks third in importance as a discrete octane enhancing blending agent for gasoline. Overall, of the 3.24 billion gallons of BTX supply available in 1986, after separation from the reformate supply stream, the 300 million gallons of toluene in gasoline represents 9 per cent of BTX supply with the balance used as petrochemical feedstocks.

MIXED XYLENES: The health effects of xylene are also well known. A 1984 EPA study, "Health Effects Assessment for Xylene," noted that pregnant women, and hence embryos, fetuses and young children, exposed to xylene should be considered a high risk sub-population.

Xylene is an aromatic compound which is a minor component of the BTX group. It has high value as a chemical feedstock. Mixed xylenes have increased in the domestic gasoline pool since implementation of lead phasedown by at least 70 percent, and perhaps substantially more at present time.

Because they are hydrocarbons, these aromatics, when released as emissions into the atmosphere, act as a chemical precursor (along with nitrogen oxides and sunlight) in the formation of ozone. Among the aromatics, however, there are varying degrees of relative photochemical reactivity. Toluene, for example, is not very photochemically reactive. Benzene, is more photochemically reactive than toluene, but is only classified as a moderate precursor of ozone. The xylenes, however, are extremely photochemically reactive, and react in the atmosphere to form significant amounts of ozone in much greater proportion over shorter periods of time than do benzene and toluene.

Reformulating Gasoline:
Reducing Aromatics and the Benefits of Ethanol:

While the EPA lead-phasedown program was perhaps the first federally mandated reformulation of gasoline, the recognition of other environmental problems has re-focused attention on steps which can be taken to "reformulate" gasoline to assure a clean-burning motor fuel. Supporters of reformulated gasoline advocate that the concentration of certain gasoline components could be altered to achieve desired environmental benefits. As an example, reducing the level of xylene could reduce formation of ground level ozone and the addition of oxygenates would dramatically reduce tailpipe emissions of carbon monoxide. Some action, such as a proposed strategy by the U.S. EPA to reduce benzene emissions from stationary sources, has been taken to date, but there is much more which can and should be done.

While we all are encouraged by the current interest on the part of the U.S. oil industry to "reformulate" their product to respond to pressing environmental needs, their sudden conversion begs two questions; first, what took them so long, and second, what do they consider "reformulated" gasoline is? As with the lead phasedown, it will take Congressional action to assure that "reformulated gasolines" meet maximum environmental standards. while many definitions of reformulated gasoline will be offered, we would suggest the following formulation:

Oxygen	3.1%	Minimum	(to reduce tailpipe emissions of carbon monoxide)
Sulfur	0.03%	Maximum	(to reduce acid rain)
Benzene	1.5%	Maximum	(to limit benzene levels)
Aromatics	25%	Maximum	(to limit photochemically reactive components)

Olefins	9-18%	Maximum	(to limit photochemically reactive components)
RvP	9.0 psi	Maximum	(to reduce evaporative emissions)

The increased use of high octane-oxygenated blending components, such as ethanol, can go a long way toward reformulating gasoline to meet all of the above requirements while assuring the continued availability of high performance motor fuels which American consumers have come to expect. Ethanol is an effective octane alternative for lead without the carcinogenic problems associated with aromatics. The addition of ethanol could proportionately reduce the amount of aromatics in the base gasoline and thus its presence for octane enhancement purposes can significantly reduce benzene levels in automobile exhaust.

Furthermore, non-benzene aromatics in gasoline, such as toluene, are precursors to benzene exhaust in the combustion process. Thus, not only does the addition of ethanol proportionately reduce the amount of aromatics in the base gasoline, its presence for octane enhancement purposes can significantly reduce benzene in automobile exhaust.

In addition to the environmental benefits, there are technical advantages to blending ethanol for octane as well. Some in the petroleum industry have suggested that one significant problem with the increased use of aromatics is the inability of heavier hydrocarbon ingredients to distribute octane evenly throughout the full gallon. The result is that the desired effect of a high octane level in the fuel is not achieved during the combustion process and performance is thereby affected.

With ethanol, that is not the case. As an alternative to aromatics, it has the ability to contribute significant octane to the front end portion of the gallon of fuel, thereby providing the proper distribution of the octane level needed while also substituting for the toxic aromatic components.

Ethyl Tertiary Butyl Ether (ETBE)

In the effort to reformulate gasoline, a new ethanol based fuel, ETBE (ethyl tertiary butyl ether) holds great promise. ETBE is a new oxygenated fuel that is produced by mixing ethanol and isobutylene and reacting the mixture over heat with a catalyst. Each gallon of ETBE contains 40% ethanol.

Today, approximately 15% of the nation's gasoline is blended with an ether-based fuel additive manufactured from imported methanol - MTBE (methyl tertiary butyl ether). As a new market

for domestically produced ethanol, ETBE has several significant advantages over MTBE. ETBE is only slightly soluble in water and has higher octane compared to MTBE, so refiners could make high octane gasolines that can be shipped in pipelines. Also, ETBE's blending vapor pressure is low, and thus provides advantages in meeting seasonal fuel volatility standards. Finally, ETBE has a greater molecular weight than MTBE, increasing producer's flexibility and providing a higher quality oxygenated fuel.

The most likely market for ETBE blends would be as an oxygenated fuel and octane booster in coastal market regions dominated by the major oil companies and established MTBE markets. There is presently no economic alternative to imported methanol as a feedstock for MTBE. However, domestically manufactured ETBE could compete with MTBE in established markets while opening new markets for ETBE blends in other regions of the country.

The domestic ethanol industry believes that over time ETBE may capture as much as 35% of the ether market. Given the lead time necessary for refiners to develop ETBE production capacity, and the growth pattern of the MTBE market, our industry estimates that an additional 350 million gallons of ethanol for ETBE manufacture may be necessary by 1995.

Because carbon monoxide (CO) reductions are relative to oxygen content, ETBE will not be as effective as 10% ethanol blends, which have an oxygen content of 3.5%. But ETBE will reduce CO emissions about 57% as much as ethanol blends while also reducing the vapor pressure of the finished gasoline. ETBE has a blending RVP of 4-7 psi, thus lowering the RVP of the blended product by about .2% in an 8% blend. This lower volatility will allow refiners greater flexibility in the use of butanes and will allow them to "reformulate" their gasoline by decreasing their reliance on aromatics.

Ethanol and ETBE have a significant number of environmental benefits. But they also have the ability to act as effective octane alternatives for lead and for toxic aromatic components. Ethanol and ETBE can be effective tools in any nationwide strategy to significantly reduce harmful gasoline benzene and aromatic levels in our fuel supplies, while maintaining the high-performance and high octane that American consumers have come to expect from their gasolines.

Little more than a theory a decade ago, fuel ethanol has become a major alternative fuel industry in the United States. It creates new jobs. It helps the rural economy. It reduces government farm program expenditures. It lessens our dependence on foreign energy imports, and improves our balance of trade. It also improves our environment by lowering carbon monoxide emissions, slowing the formation of urban ozone, and providing an alternative to toxic aromatic compounds. By requiring the increased use of oxygenated fuels we can all take a confident giant step toward cleaner air.

Vehicle Research for Future Fuels. Roberta Nichols

Thank you very much for the nice introduction and it is indeed a pleasure to be here. I have brought along a set of slides to share with you some of the things we have been doing at the Ford Motor Company over the last decade. Because of the energy crisis in the seventies, we made a serious commitment to developing the technology for the alternative fuels, related to transportation use. It started out very much as an energy program, as did the California programs, but along the way we discovered there was a potential for improvement in air quality with the use of some of these fuels. There are varying amounts of improvement, and you have to ask which particular environmental question are you addressing when you talk about the various fuels.

We begin by looking at the various potential candidates based on cost, reasonableness of engineering of the vehicle, and the resource being supplied for the long term in the future. There are primarily gaseous and liquid fuels. Of the gaseous fuels, no hardware work has been done with hydrogen, because the theoretical analytical studies indicated it was too expensive at the present time for transportation use, about ten times the cost of present conventional fuels. If global warming was to become an escalated problem in the future, there could be new interest in hydrogen regardless of cost, and there is always the possibility of extraction from sea water with inexpensive energy.

Of the other gaseous fuels, we saw an opportunity for natural gas and propane in the near term. For the propane, being a by-product commodity, we never thought that more then two to three percent of the vehicle population could be fueled with propane, but that was enough to launch a study of propane, which eventually led to some production. In the case of natural gas, again we saw a fuel that was environmentally benign in many ways, as well as very cost effective for the fleet operator.

Of the liquid fuels, coal-derived or shale derived hydrocarbons were investigated briefly, and the conclusion was reached that when these hydrocarbons were distilled or refined to the same specifications as today's petroleum based fuels, there is no difference in function in the engine. So work was concentrated on the alcohol fuels, in Brazil ethanol, and in the North American continent, methanol and some ethanol.

The present status of the Ford alternative fuel program:

- production of a medium duty propane truck, 7L engine, sales about 750 units per year,
- a package for light duty truck, 4.9L engine, and

- from 1982-84 produced a passenger vehicle, 2.3L engine.

After the price of gasoline dropped, there was no longer the cost incentive for the consumer to purchase these vehicles. Initially, there was about a two and a half year payback. There was about a $700 incremental cost to the propane vehicle above the cost of the gasoline vehicle. Based on 12 000 miles per year, and lower cost of the fuel, a payback was realized. Here in Ontario you had an instant payback because there was no excise tax on the fuel, and more important, there was no sales tax on the vehicle. There was also a $400 incentive given by the federal government for the purchase of a vehicle.

Research work was done with vehicles using both liquid and compressed natural gas. Though liquified natural gas had a range about double the compressed natural gas, highly trained personnel were required to refuel the vehicles, because of the potential for serious tissue damage from dealing with a cryogenic fuel at very, very low temperatures. Most of the effort was concentrated on compressed natural gas.

During the research, a dual fuel vehicle was also built, but the decision was made to build dedicated vehicles where the primary goal was to equal the performance of the equivalent gasoline vehicle. Many fleet operators liked the lower price of the natural gas, and liked having an alternative energy supply in case of crisis, but did not like the power loss. Many of their drivers were flipping on the gasoline most of the time. With a dedicated vehicle, and increasing the compression ratios on the engines, performance of the natural gas vehicle was equal to that of the gasoline vehicle. There was a fleet of 27 Ranger trucks in the field for almost five years, and these were returned to Ford last spring. Engines are being examined and found in excellent condition. The mileage on the vehicles ranged from 40,000 to 149,000, the highest mileage vehicle was operated in Alberta. The first engine dismantled (at 77,000 miles) did show some signs of still having valve recession, which will require more work, but the leak down rates associated with that were still within specifications. High quality inserts had been put into that cylinder head, so that area has to be carefully watched.

Alot of engine design work for ethanol vehicles has been done for Ford Brazil. Afew years ago our sales were about 99% of the total at Ford Brazil. Since then it has dropped abit due to three primary reasons.
1) Most of the ethanol is produced by industry making both sugar and fuel. Fuel is made from sugarcane in Brazil. Afew years ago, the price of sugar in the world increased, encouraging producers to push production in the direction of sugar. This created a fuel shortage, and the problem was

increased by the larger number of vehicles coming into the marketplace (about 40 % of vehicles in Brazil run on ethanol fuel).
2) Crude petroleum still had to be imported to make diesel fuel, and a surplus of gasoline was created as the ethanol use grew. The gasoline was only 75 octane and not saleable on the world market. The reason for the low octane was the addition of 20% ethanol to all the gasoline increased the octane to a desirable level.
3) Oil has been discovered on the Amazon. About one year ago, Ford was approached about the possibility of introducing flexible fuel technology in Brazil to help balance their supply and demand of various fuels.

In the United States and Canada, Ford has concentrated on methanol vehicles. In 1981 40 dedicated vehicles were delivered to California, and in 1983, 30 flexible fuel vehicles (now 660) were built. Effort has been put into the flexible fuel vehicle, as the vehicle that can make the transition from the old fuel to the new fuel. The vehicle can run on methanol, gasoline or ethanol.

After having done all this work with the various fuels, the conclusion reached was that methanol was the best candidate for long term replacement of petroleum based fuels. As an engine builder, I must add that either alcohol, ethanol or methanol, from a performance, fuel efficiency, emissions standpoint is equally good. If ethanol could be competitive in price, it would probably be the alcohol of choice, because it has a better energy density.

There is a large resource for the production of methanol. Right now most of it is made in the world from natural gas, but it can also be made with known technology from coal. There is a coal to methanol plant in operation in Tennessee, and a couple in operaton in South Africa. The United States has about three to four hundred years of coal.

Current government interest is based primarily, near term, on the potential for improvement in air quality, with long term interest in energy security as well. My sense is that the energy security part of the issue is returning, and there is no question that it should be a consideration. Federal legislation was signed into law on October 14, 1988, by President Reagan, which provides an incentive for the auto industry to want to produce vehicles that can run on ethanol, methanol, or natural gas, because the legislation recognizes those fuels as being non-petroleum, except for the portion of the fuel that is actually gasoline. Ford is recommending an 85% alcohol, 15% gasoline fuel blend. For example, if you have a vehicle which gets 15 miles per gallon on M85 or E85, it becomes a 100 mile

per gallon vehicle, which encourages management to consider the incentive. This incentive does not cost the government any money (not a subsidy).

The launch of a new fuel, and a dedicated fuel is extremely difficult, as experience with the California program taught Ford. Many drivers had anxiety wondering if they were going to find another refueling station for their dedicated vehicles. So the flexible fuel technology bridges the gap between fueling stations, and allows that infrastucture to build in an orderly way. Having the vehicle in the marketplace, provides the incentive for the fuel supplier or the retailer of the fuel, to bring the refueling stations into the marketplace.

A summary of the vehicles in the field include the Canadian fleet of 30 Crown Victoria's, 19 of which are in the program partly funded by the Ontario and Federal government and began in September of 1986. Those vehicles are going into their fourth winter. The experience gained with these vehicles encouraged the building, and delivery, of 210 additional Crown Victoria, flexible fuel vehicles, for delivery to California by the end of 1989. Two of the vehicles in the Canadian program are operating on E85 fuel, 85% ethanol and 15% gasoline. They are in operation at St. Lawrence Starch in Toronto.

There was an ethanol fuel study as part of the Canadian program, such as engine dynamometer work. The operation was at base compression ratio, but 10%, 50% and 85% ethanol blended fuels were assessed. One of the interesting features of the alcohols is that at the 50% level, almost all the benefits of the 100% level are derived, in terms of power and fuel efficiency, because the properties of alcohol are so different than gasoline that they become the dominant factor. The E85 was mapped on the engine stand so that calibration could be put into the two vehicles operated by St. Lawrence Starch. The vehicles were emission tested before delivery, and the emission results were quite similar to those of the methanol or gasoline. The improvement in air quality does not come from the difference in tail pipe emission level, but rather, the way the exhaust reacts in the atmosphere.

The vehicles were also cold start tested, as were the methanol operated vehicles, and the same starts were achieved at -30 C (-20 F) in about 5 seconds. The percent alcohol gauge on the vehicle was the only thing changed, because it was calibrated for methanol, and had to be recalibrated to give the correct alcohol reading for ethanol. This gauge may not be included in vehicles designed for high volume production, as the purchaser might interpret the output literally, and not take into account the variance in gasoline in the field, or temperature discrepancies which can cause deviations from expected

readings. The most important information to the customer is knowing how many more miles can be traveled before refueling is necessary, and that is called a "distance to empty" gauge. This gauge does calculate correctly for whichever fuel is in the tank.

The flexible fuel vehicle operates on methanol, ethanol or gasoline without any action on the part of the driver. There is an optical fuel sensor in the Ford vehicles, based on refractive index. It measures the percentage of alcohol, sends a signal to the computer, which adjusts the fuel flow, spark timing, exhaust gas recirculation etc. to optimize the fuel in the tank. The compression ratio is not increased, because the vehicle should also operate normally on unleaded regular gasoline. On introduction of new technology, the linkage of operation to the known gasoline fuel is considered important.

There is higher performance with the vehicle operating on the alcohol fuels compared to gasoline. These results were obtained using the same vehicle with different fuels, and tested by professional drivers. The same difference was noted on the engine dynamometer -- about 5-7% on the 5-L Crown Victoria. There is also some improvement in fuel efficiency at the part load operation, because of the higher octane quality resulting in more agressive ignition timing.

Engine changes were needed, a higher flow rate for the injector was required, idle stability when the vehicle was operating on gasoline had to be assured, and alot of material changes. The optical sensor has been changed in design, but the concept is the same. There is a light emitter and a light receiver, in the schematic, there is a glass rod with a light emitter on one end and a receiver on the other. The glass rod is surrounded by fuel. At the interface between the glass rod and the fuel, there is bending of the light, and depending on the alcohol content of the fuel, more or less light gets reflected back. The intensity of the light received at the other end changes. The signal is calibrated from 0 to 100 percent alcohol.

Data showing difference in power with the vehicle testing on the Escort, indicated almost a full second reduction in the 0-60 time, and for the 5-L Crown Victoria (a heavy vehicle) about 0.5 sec., both values being significant.

One area needing more work is fuel specification. One of the reasons for recommending 85% methanol and 15% gasoline, is that at 100% methanol you cannot see it burning. Ethanol can be seen burning because it has two carbon atoms and soot is formed when an alcohol has two or more carbon atoms. Although little particulate formation with methanol is one of its virtues, in the case of fire, on the vehicle, in the factory, or at the

refueling station there is need to know of the danger. Racing car drivers have been seen to react in an apparently strange manner, and have been found to be on fire.

Another concern is due to the broad flammability limits of alcohol. The potential for ignition of the vapour above the liquid in the tank exists at normal ambient temperatures. Addition of 15% gasoline lowers the temperature to one similar to gasoline.

Three years ago there was a major breakthrough in the technology to cold start these vehicles. Canadian results played a major part in contributing to this breakthrough. There is an additional injector upstream. Ethanol has an even harder cold start than methanol. Ethanol has a vapour pressure of 2.3 psi, and methanol is 4.6. Neither has sufficient vapour pressure to start below about 45 F (7 C). Even with the 85% mixture difficulty is encountered below 20 F (-6 C. Another reason ethanol has a more difficult cold start is that it has a higher boiling point.

Long term engine durability has always been an issue. It is not as much an issue with ethanol, because it is not as chemically active from a corrosion standpoint as methanol. One of the California high mileage vehicles was returned to Ford by Los Angeles, and it was torn down and measured. Ford has 23 million miles of service on the 660 vehicles in the field. Although many of these vehicles have been in the mild climate of California, many miles have been driven here in Canada, which has been helpful, because the major concern for durability has been with the short trip cold climate performance.

Emission compliance in aldehydes is one of the major open issues to be solved. Aldehydes are formed at a higher level than they are with gasoline, and need to be controlled below about 55 mg per mile, according to the air quality models, in order to realize the reduction in ozone. California has set an emissions standard of 15 mg per mile beginning in 1993, and although Ford vehicles have attained the 55 mg/mile standard, they have not reached the standard of 15 set by California. Right now, Ford could probably meet a 50 000 mile standard of 30 mg/mile.

Emission data from the car built in 1986, and the average for the vehicles delivered to the field is available. It looks like the hydrocarbon is different between the M85 and E85, but it isn't really, because the flame ionization detector instrumentation of the Federal Test Procedure sees the ethanol and methanol differently, with different sensitivity to the two alcohols. If more sophisticated equipment is used, the levels are found to be similar, not different as with the FTP-FID test

procedure. Vehicles are returned, periodically, for emission testing. FFD-1 is the vehicle Ron Bright, Director of the Environment and Safety Office, Ford Canada drives. Test 1 and test 2 average 28 mg per mile.

Why does methanol give a reduction in ozone? Relative reactivities compared to the more common hydrocarbons emitted from gasoline, show methane with the lowest reactivity of all. Methanol has lower reactivity than most hydrocarbons. When unburned methanol, which is the primary hydrocarbon exhaust emission, is emitted into the atmosphere, there is less ozone formation than with the hydrocarbons present in the exhaust of gasoline burning engines. This is where the improvement is realized, not with a lower tail-pipe emission. Ozone is the most difficult air pollution problem to solve. Although studies do not show big improvements, in the range of 3-13 %, it is still a significant number, and legislators agree. The main objective in trying to bring the aldehyde emission down is to get the engine and the catalyst warm as quickly as possible, because all of the aldehyde is formed in the first two minutes of operation. The time frame must be reduced to about 30 seconds to reach the level of the gasoline vehicles. The same vehicle on gasoline emits about 7 mg per mile of aldehyde.

Dave Elliott did work using one of the Crown Victoria's in the Canadian program and testing the full range of fuels and found that the level of aldehyde goes up as the alcohol content goes up. There have been long discussions with the Environmental Protection Agency about the 85% or 100% alcohol level. EPA would like the M100, Ford wants the 85% level for the safety reasons identified earlier, plus the inability to cold start M100. ford has done alot of work to show that the air quality benefit is just as good, and maybe better with the 85% methanol, especially if the engine is not worn out as fast trying to cold start.

The optical fuel sensor reliability still needs alot of development and durability testing. It is a new technology, and it is the key to the success of the flexible fuel vehicle. Recently, a couple of the Crown Victorias were torn down at Shell of Canada, with two vehicles over 50 000 miles, and the visual assessment reported satisfactory condition. Material compatability is especially important to study where elastomers are concerned. The change in reaction of material to the different levels of alcohol has been studied for maximum swell. The one case was 65% fluorine content for a fluorocarbon material, and by increasing the fluorine content to 67% -- just two percentage points -- the swell was reduced to an acceptable level. Controlling specifications for elastomers or polymers to those restricted controls is not always possible in high volume production.

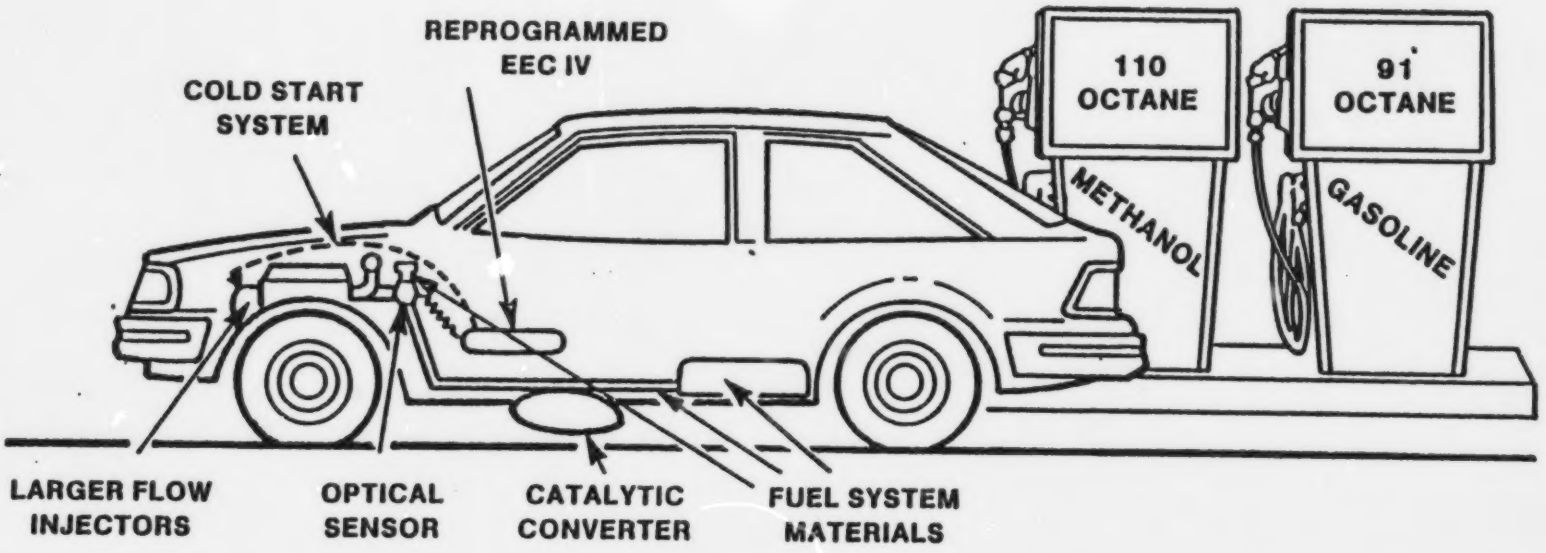
Driving range is probably the number one marketing issue for the flexible fuel vehicle. The energy density of the alcohol is less than that of gasoline, which means it takes more volume to go the same distance down the road. That does not mean there is less fuel efficiency. The fuel efficiency is actually better, which means that miles per energy unit is better than that of gasoline. There will have to be more tank volume, and this is a challenge with today's aerodynamic designs. Methanol, on an energy basis, is about half that of gasoline with M100, and with M85, about 70% more fuel is required to go the same distance down the road. With ethanol, E85, about 30 % more fuel would be required, as ethanol is more energy dense than methanol. The price of the alcohol is a key question. In California, ARCO and Chevron have put in additional refueling stations, and the posted price in September 1989, methanol (M85) was selling for $0.699. On one side was unleaded regular at $1.10, on the other side was unleaded premium at $1.25. In terms of gasoline equivalent, or cost per mile basis, the $0.699 is like $1.16 gasoline.

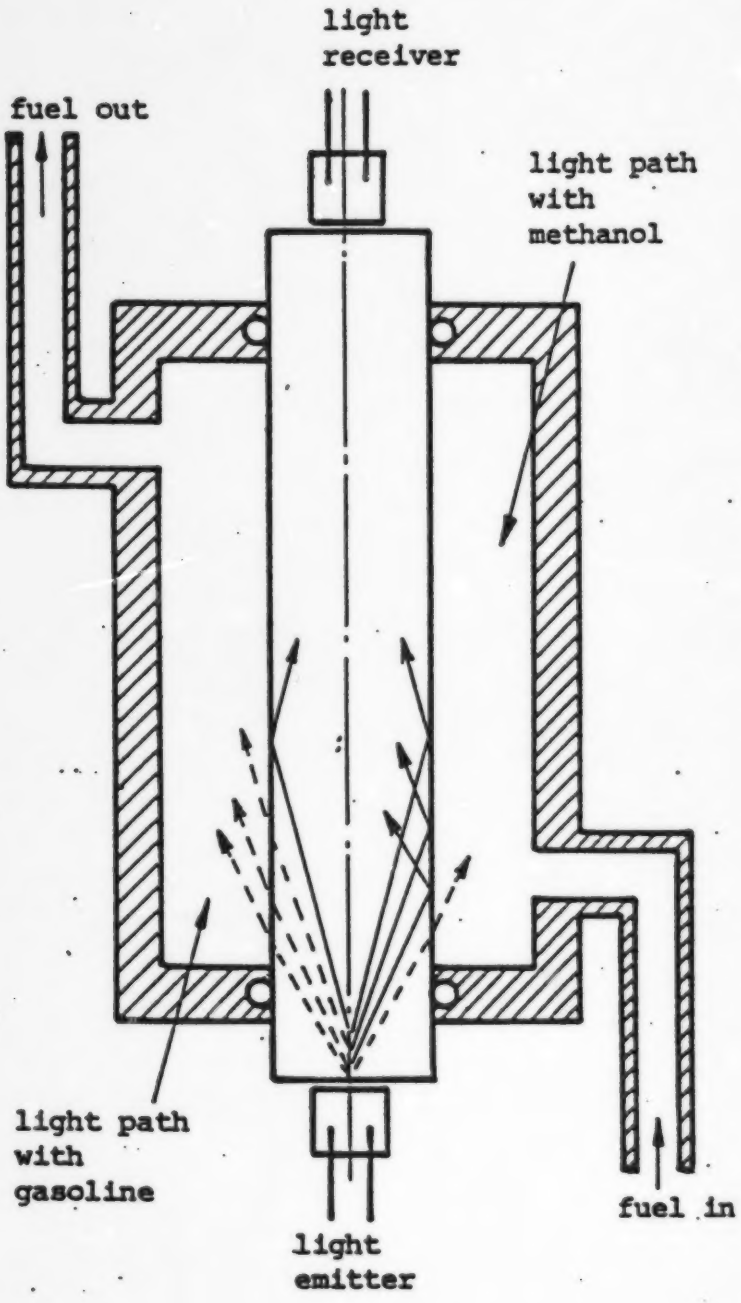
In conclusion, I would like to address the larger issue of environmental concerns, one being global warming. The auto industry has always been an easy target, and recently has become the target of increases in CAFE -- corporate average fuel economy -- because of global warming concerns, and meeting reductions in carbon dioxide. The carbon dioxide from the vehicle is small compared to that from other sources. There are bigger ways we can make a contribution, and one of those is getting the CFC's out of the vehicles, or the freon used for air conditioning. The rate of global warming with the freon is much higher than that of carbon dioxide. Also, carbon dioxide has a way of balancing itself in nature through creation of biomass. This tendency towards equilibrium does not apply to CFC's. The discussion in Washington relating to the Clean Air Act, includes tighter tail pipe emission standards. Recent estimates of improvement in emissions by going to tighter tail pipe standards is less than one percent. Where the big improvements can be realized is:
(1) in fleet turnover,
e.g. ten years from now, based on current vehicles and fuel, there will not be a region in the U.S. out of compliance with carbon monoxide levels
(2) in reducing volatility of the fuel, which has increased in recent years, and/or recovering present running losses.

The durability experience based on vehicle fleets has been quite satisfactory. More experience is needed in the cold climates. Emission data support the improvement in air quality. The flexible fuel vehicle technology can implement the transition from the old fuel to the new.

FORD FLEXIBLE FUEL VEHICLE

MAJOR UNIQUE COMPONENTS





Optical fuel sensor schematic.

THE RESULTS AND POLITICS
OF
OXYGENATED FUELS IN COLORADO

Presented by Tony Massaro
Director of Environmental Affairs
City and County of Denver, Colorado

LETS CLEAR THE AIR CONFERENCE
Canadian Renewable Fuels Association
Biomass Energy Institutue
Toronto, CANADA
October 18, 1989

Oxygenated fuels are used in Colorado to reduce the carbon monoxide pollution levels emitted from cars. Currently the program requires all gasoline sold along the Front Range of Colorado, from Fort Collins-Greeley to Colorado Springs, during the four winter months contain a minimum oxygen content of 2% by weight. This program is the first of its kind in the nation. How did Colorado get here and where is it going?

The Colorado oxygenated fuels program is guided by three overriding principles. The first is that the program is an air quality program, not a farm support program. The second is that the consumer should have freedom of choice among oxygenates in the marketplace and the third is that the introduction, use, and expansion of oxygenated fuels needs to be done in small, incremental changes.

THE PROCESS

In early 1986 the Colorado Air Pollution Control Division (APCD) proposed to various elected officials and policy-makers pursue the use of oxygenated fuels as a pollution strategy in Denver. The APCD had test data demonstrating the the use of ethanol provide for significant reductions in the tailpipe emissions of carbon monoxide (CO), the most prevalent pollutant in Denver.

Governor Lamm's Oxygenated Fuels Task Force. Governor Lamm established the Governor's Oxygenated Fuels Task Force to investigate the

feasability and advisibility of using oxygeated fuels as a pollution control measure. That Task Force was comprised of representatives from air pollution agencies, local governments, state legislature, ethanol producers, oil companies and car companies and was chaired by a representative of the Governor's Office. The task force spent many long hours reviewing the distribution sysxtem for gasoline in Colorado and its compatability with the use of oxy-fuels. The Task Force also looked at possible air quaility benefits as well as the cost to the consumer. The Task Force decided to recommend to the area pollution agencies the adoption of regulations mandating oxy-fuels during the winter months in nonattainment areas of Colorado.

Metro Air Quality Council. The air quality lead planning agency for the Denver metro area was the Metro Air Quality Council (MAQC). The MAQC was formed in 1985 by Governor Richard Lamm and Denver Mayor Federico Peña. The MAQC was a bipartisan, public-private sector partnershipwhich brought all interested parties to the table as the planning entity for air quality. This structure allowed the MAQC to be an extremely effective group. The MAQC accepted the recommendations of the Oxy Fuels Task Force and agreed to include such requirements in the metro area's interim State Implementation Plan (SIP). The twenty-one member group then pledged to use its influence to see the recommendations enacted into regulation. The MAQC is now replaced by a new organization called the Regional Air Quality Council (RAQC). The RAQC is very similar to the MAQC, except it has significantly expanded participation of local governments.

Colorado Air Quality Control Commission. The Colorado Air Quality Control Commission (AQCC), by authority of the Colorado Air Quality Control Act of 1977 has the authority to regulate motor fuels for the purposes of air quality objectives. After several days of hearings and much debate the AQCC, in June 1987, adopted a regulation requiring the sale of oxy-fuels beginning January 1, 1988 through February 28, 1988 at an oxygen content of 1.5%. Beginning November 1988 the oxygen content was required to be 2% and the program was to last four months, until the end of February 1989. This year the program will be the same as last year.

The AQCC decided to start at 1.5% and for only two months to allow the oil companies time to implement the requirements. The Commission wanted to be responsive to industry concerns about their ability to meet the requirements on such short notice. The oxygen level was also set low so that consumer acceptance of the program would start off well. Additionally, a low oxygen content was designed to allow both ethanol and MTBE to compete in the marketplace. When Colorado adopted the regulation, the maximum

allowable concetration of MTBE was only 2% oxygen. Now with the Sun waiver MTBE can be blended up to 2.7% oxygen, or 15% MTBE.

THE PLAYERS

In addition to the entities whose roles I have already described there were many other players in the debate over the mandatory use of oxygenated fuels.

Oil companies. From the beginning the major oil comapanies in the United States have been opposed to Colorado's program. The lead was taken locally by Amoco. They were the most critical and vocal in fighting the program at each and every step. They have also been behind the repeated attempts in the Colorado State Legislature to kill the program. The oil industry formed a group called the Consumers Environmental Awareness Project (CEAP) to distribute information about the program. This group is now called Consumers For Competitive Fuels. Failing to kill the program, the oil industry continues to fight to keep the oxygen level at as low a level as possible. Last year the Governor tried to pressure the oil companies into providing more ethanol-blended fuel. While they seemed to have agreed with the Governor's suggestion, none of the companies actually made any effort to market ethanol.

Ethanol companies. The ethanol companies have also played a key role in the program. They have supported the program from the beginning. They formed a group called Coloradoans for Clean Air to distribute information. They also have trained hundreds of mechanics about oxygenated gasolines and the impacts they can have on automobiles. They have continued to push for the oxygen levels to rise, eventually all the way to 3.7%. Colorado has resisted raising the oxygen level that high because it would eliminate the freedom of choice for consumers. MTBE would not be available at that oxygen level.

Car companies. The Motor Vehicle Manufacturers Association (MVMA) and their members were initially opposed to the program. They were not supportive of the Task Force recommendations. When the oil companies stated that oxy fuels might hurt your engine the car makers did not disagree. By their lack of defense of their products, the car makers contributed to public apprehension. General Motors is now recommending the use of oxygenated fuels in its owners manuals for 1990 model year cars.

State Legislature. The Colorado State Legislature has repeatedly fought back attempts to repeal the authority of the AQCC to regulate fuels. I anticipate that this will be an annual event in the legislature. In the event of passage of some type of restriction the possibility exists for a veto from the Governor, a very visible and vocal supporter of the program.

Colorado Springs. Colorado Springs continues to be the pocket of greatest resistance to the program by the general public. Colorado Springs is very conservative and opposes government regulation, particularly if the regulations are implemented by unelected bureaucrats. In addition, there is organized opposition to the requirement. The public officials in Colorado Springs have not been visible in support of the program and many have been visible in opposition. Even here, after two years opposition is weakening and, according to polls, never was the majority of the population.

University of Denver. The University of Denver has been a recent player in the debate. Some professors at the University take issue with the APCD's figures on the effectiveness of the program. They also express concerns about the impact of oxygenates on ozone and formaldehyde emissions. While the AQCC has listened to their concerns and the response of others, DU persists in raising objections to the program. They are seen by some state legislators and others as a reputable source and the concerns they raise are getting increased attention by many.

THE RESULTS

Last year was the second season for Colorado's oxygenated fuels program. The program ran from November 1, 1988 to March 1, 1989. During that time all gasoline along the Front Range of Colorado, from Fort Collins to Colorado Springs, must contain a minimum oxygen content of 2%. Last year this program was responsible for reducing carbon monoxide pollution in the metro Denver area by 12%, up from the 8% the previous year. Last year we violated the federal eight hour standard for CO on 10 days, down from 16 the year before and 33 the year before that. This makes it one of the most effective carbon monoxide strategies in the country, from a cost-effectivenss standpoint.

Only 6% of the fuel sold was ethanol, the rest was MTBE. This is a concern to air quality planners because ethanol blended at 3.7% oxygen reduces carbon monoxide more than MTBE blended to 2% oxygen. This is also a concern to farmers and ethanol producers and marketers. Sixty-five service stations were issued compliance orders for failing to have enough oxygen in the fuel.

The costs to the consumers is between zero and two cents a gallon. However, the consumer does not actually experience an increase at the pump. Gasoline prices traditionally fall with the onset of winter so any price increase is more than offset by decreases caused by other market factors. In fact, just last weekend, the price at my local service station fell six cents a gallon, and it was their first shipment of oxygenated fuel this year.

THE FUTURE

Where will Colorado go from here? Last spring the MAQC recommended to the AQCC an increase in the oxygen amount to 2.7%. This would still allow MTBE to compete in the marketplace and maximize the air pollution benefits. The Commission chose not to act last spring due to a busy schedule and a short lead time for the industry. The same proposal will be presented to the Commission again this year. There may also be a proposal to establish an average oxygen content standard of 3.1%. By allowing banking and trading, MTBE can still find a place in the market, even at this oxygen level. I predict that the oxygen level will rise in Colorado next season, to at least 2.7%.

If the percent ethanol penetration fails to increase in future years some people will begin to advocate a fixed market share, like that in Phoenix. The banking and trading program then begins to look very positive. The introduction of ETBE into the Colorado marketplace will probably happen soon, possibly before the beginning of the next year, if ETBE gets favorable tax treatment from the federal government.

Other areas of the West with similar problems hvae implemented oxy-fuels requirements for this season. We now see Phoenix and Tuscon with programs, along with Albuquerque, Las Vegas, and Reno. The mostly likely area in the East to implement such a program would be New York City, but that is probably at least a year or two away from happenning. Another indication of the widespread acceptance of oxygenated fuels as a clean air strategy is its inclusion in every major piece of Clean Air Act legislation proposed in Congress this year.

Thank you for the opportunity to speak to you about the results and politics of oxygenated fuels in Colorado.

EFFECTS ON THE ENVIRONMENT OF THE FUELS WE ARE USING

A Presentation by
Colin F. W. Isaacs
Environmental Consultant

to the
Let's Clear The Air
forum

of the

Canadian Renewable Fuels Association

Toronto
Wednesday 18 October 1989

I want to commend the Canadian Renewable Fuels Association and the Biomass Energy Institute for this "Clearing The Air" seminar. Canadians right across the country are concerned, and rightly so, about the burning of tropical rainforests, yet most are totally unaware that we are adding more than twice as much carbon to the atmosphere through burning of fossil fuels, coal, oil and gas, as is being added through deforestation. A very large part of our contribution to the greenhouse effect comes from the burning of fuels for transportation.

I don't intend to limit my remarks today to the greenhouse effect, but I do want to make the point very strongly indeed that in my opinion global climate change, the greenhouse effect, is by far the biggest environmental challenge that this planet has ever faced. Every previous challenge, including acid rain, ozone depletion, toxic chemical contamination of water, food and air, and many others, comes with the promise that if we clean up our act, stop our polluting habits, then the complex combination of natural systems that we often call Mother Nature will, over a very long period of time, be able to remedy the damage. The greenhouse effect comes with no such promise - indeed it comes with the understanding that much damage is already done and that reversal of that damage is highly improbable within the span of many dozens of human generations. With global climate change the bright light

at the end of the road is hard to find: the incentive that must drive us is the recognition that if we do not very substantially reduce our use of fossil fuels as quickly as possible then the possibility that natural systems will flip to a new mode incapable of supporting human life as we know it becomes an ever increasing probability. I will return to the issue of the impact of fossil fuel use on global climate change after I have reviewed some other slightly less scary issues.

Are there any slightly less scary issues surrounding our gross abuse of fossil fuels? For today's generations, the most alarming effect of mass motor vehicle use must be the enormous damage to human health that it is already causing. Researchers at the University of California estimate that the use of gasoline and diesel fuel in the United States alone may cause up to 30,000 deaths every year as a result of air pollution. The American Lung Association estimates that air pollution from motor vehicles, power plants and industrial fuel consumption costs the United States $40 billion annually in health care and lost productivity. At least one half of this comes from burning of derivatives of crude oil. In typical "let's pretend we don't have any environmental problems" fashion, comparable data for Canada are not available, but we do know that urban air quality in several of Canada's large cities, especially including Toronto, rivals that of many U.S. cities when it comes to toxicity and poor quality and there is more than sufficient reason to believe that at least the usual ten to one ratio will apply, giving us figures of 3,000 deaths and $2 billion in health care and lost productivity costs each year. In case anyone still thinks that air pollution is the preserve of big business let me share with you some OECD data: in OECD member countries, that is western first world countries including Canada and the U.S., cars, trucks and buses contribute 75% of carbon monoxide emissions, 48% of nitrogen oxides, 40% of hydrocarbons, 13% of particulates which also serve as carriers for highly toxic trace organics, and 3% of sulphur oxides. Catalytic converters can reduce, but not eliminate, some of these, especially the carbon monoxide and hydrocarbon emissions, but catalysts can increase the seriousness of the sulphur oxide emissions and they do nothing positive for the particulates, perhaps the most worrisome part of the toxicity of fossil fuel burning.

Ranking of environmental problems has always been something that I have tried to stay away from: no one knows which of the

environmental threats we face will be the one to send us over the brink; scientists can't yet tell us the total environmental impact of any one problem area; and ultimately they are all interconnected, both because of the migration of contamination and its effects between air, water and soil and also because it is our historically ignorant treatment of the planet as if it could yield unlimited resources and accept unlimited quantities of wastes that is the fundamental cause of all these problems. Nowhere is the synergistic effect more obvious than in the area of low-level ozone. Low-level ozone, also known as photochemical smog when concentrations are such that people with respiratory disorders start to die from it, is formed by the action of sunlight on the nitrogen oxides and hydrocarbons that are emitted from vehicle exhausts. Low level ozone is a serious contaminant in many North American cities: Toronto experienced a particularly unhealthy dose last summer during the long spell of hot weather and regionally trapped air mass. With global warming such extended periods of really serious photochemical smog are likely to become much more prevalent; even today Toronto exceeds U.S. National Ambient Air Quality Standards on as many as ten or eleven days per year. It's interesting to note that we don't have any National Ambient Air Quality Standards; our standards are called objectives: they lack legislative bite and suffer several technical inadequacies. It's also useful to note in passing that low-level ozone is a serious pollutant that does nothing to help with our stratospheric ozone layer depletion problem. Canadian media and political reports on the so-called acid rain initiative taken by President Bush earlier this year completely missed the point: President Bush's announcement was an air pollution control program because President Bush knew that if you control air pollution you automatically control acid rain. Clearly Canadian governments did not want us to know that President Bush was announcing an air pollution control program that went way beyond anything that Canada had been asking the United States to do and way beyond anything that we are doing to control air pollution in this country. The air pollution problem in Canada is one that has been almost ignored by environmental groups, by government and by the public during the last ten years, yet our air pollution problem in major cities, where most Canadians live, continues to be serious. If we take as serious the Canadian Ambient Air Quality Objectives, the closest we have to the U.S. National Ambient Air Quality Standards, then it is of considerable concern to note that the annual mean of all monitoring station readings across Canada exceeded the maximum

desirable concentration for particulates which is 60 micrograms per cubic metre during all of the 1970's, and that, while the national mean is now somewhat below the maximum desirable, the mean in many individual cities is still above the maximum desirable. Ten per cent of air quality readings in many cities fall above the maximum acceptable concentration of 70 micrograms per cubic metre. Ten per cent of readings for nitrogen dioxide in Canada also fall above the maximum desirable concentration in the national Ambient Air Quality Objectives, while the annual mean of all monitoring station readings for ozone falls above the Maximum Acceptable Concentration in the Ambient Air Quality Objectives. In controlling air pollution, especially that coming from automobiles, we still have a long way to go!

While I am talking the environmental effects of transportation fuels I can't completely ignore the lead problem, even though lead itself as a problem is now on the way out in this country. With tremendous help from the Canadian Renewable Fuels Association, the Canadian Medical Association, the Association for Children with Learning Disabilities (which now has a new name that I can't remember) the environmental groups in this country were finally able to persuade the federal government to phase out use of lead in gasoline. Nevertheless, leaded gasoline continues to be with us as a very serious and unnecessary threat to human health for at least another year, it is still widely used in other countries, and the environmental impact of some lead substitutes has still not been subject to thorough public review and scrutiny.

Let me move to the impact of transportation fuels on ozone depletion. While most of the focus has been on chlorofluorocarbons, or CFCs, from aerosol propellants, foam plastics, cleaning solvents, and refrigeration and air conditioning equipment, some scientists are now postulating that sulphates may also play a role in catalysing the same ozone destroying reactions as chlorine from CFCs. If such is the case, the urgency with which we approach the sulphur dioxide problem will increase and the use of catalytic converters will actually be adding to ozone depletion.

Let me switch from the downstream, or consumer, angle, to the upstream: exploration, extraction, transportation and refining. I constantly remind people that the Exxon Valdez was carrying not some esoteric chemical that we'ld never seen before but simple crude oil, to be refined into gasoline to power our automobiles.

Demand and supply are inextricably interconnected: if we don't want Hibernia, if we don't want to undertake drilling which may pollute hundreds of square miles of almost uncleanable arctic ocean, if we don't want supertankers carrying their loads through treacherous waters off our coasts, we must find ways of reducing our gasoline consumption. While the number fluctuates from year to year, there are roughly 1000 spills of crude oil and petroleum products into the Canadian environment each year from ocean tankers, truck and train tank cars, and pipelines. Did you know that we have more than 248,000 kilometres of petroleum pipeline in Canada! Tens of thousands of tonnes of petroleum are being spilled into the Canadian environment each year and if we want to protect the environment and wildlife from those spills, we can help significantly by reducing our demand. As time goes by the number of, and environmental damage caused by, spills is likely to increase as exploration and extraction moves to more hazardous parts of the globe. Extraction itself is also damaging to the environment. Many Canadians are very concerned about the environmental impact of mega-projects such as Hibernia. Drilling in the Beaufort sea poses a significant of risk of environmental damage. If you have seen tar sand extraction on television, you'll know that the strip mining used at Fort McMurray is causing immense damage to tens of thousands of hectares of muskeg.

It's not just the strip mining that causes the problem. Extraction of those tars sands manages to make one heck of an environmental mess. Waste production poses an immense problem and its not just the solid and liquid wastes. Tar sand extraction is now becoming a major source of acid rain: tar sand extraction sends more than 500 tonnes of sulphur dioxide into the atmosphere every day. Refining even of regular crude adds sulphur oxides and hydrocarbons to the atmosphere: indeed, as the oil companies and car manufacturers begin to get hydrocarbon emissions from automobiles a little more under control, total hydrocarbon emissions to the air from crude oil production and from refining are projected to increase by more than 70% over the period 1985 to 2005.

Let me return to the issue of global climate change. On top of our own energy use, we must consider the very real need to provide energy supply to accommodate the undeniable aspirations of the developing world. At present per capita utilization, clearly inadequate in the growing world, the growing world population will mean an increase of 40% in global energy consumption by 2025. Much

of this energy use will be fossil fuel. If recent worldwide consumption growth rates of about 3 percent per year continue, fossil fuels could contribute to the atmosphere 10 billion tons of new carbon annually by the year 2010. If developing nations are to achieve uniformity with our present consumption levels, an approach that I cannot in principle deny to the people of third world countries, the increase in global energy consumption by 2025 would be about 550%. Both figures are from the World Commission on Environment and Development, both are extremes, and both are quite scary, especially when we consider that atmospheric carbon dioxide concentration is already growing at a rate of 0.4 per cent per year, and, according to respected scientists, is already substantially above the highest concentration experienced on earth in the past 160,000 years.

We are facing not just a greenhouse but a hothouse. Global climate change is no longer just in the realm of science fiction but is a phenomenon that has the potential to substantially destroy human life within the lifetime of our children's grandchildren. This talk is not the one I give to audiences of school kids.

Let me come to the hope! It's not too late, yet. We cannot avoid some climate change, just as we have not avoided acid rain, or toxic contamination of our fresh waters, or serious urban air quality problems, but I am convinced that we can slow and ultimately reverse the negative trends.

In the short term the priority is to do everything we can as quickly as we can. Wherever we are presented with an opportunity to reduce our impact on the environment, we must take advantage of that opportunity. There is no doubt at all that biomass and biomass derived fuel has the potential to reduce our impact on the environment, to reduce the need for environmentally hazardous drilling and transportation, to reduce the quantity of fossil carbon we return to the atmosphere, to reduce our urban air pollution problems, to reduce our contribution to the greenhouse effect. When environmentalists urge the Federal government to adopt California air quality controls, as they did again in a brief called a Greenprint for Canada given to Prime Minister Mulroney in June of this year, they are met with the response that there is no need for California-type measures because we don't have their air quality problems. I hope I've shown today that not only do we share their problems because we are all occupants of the same

fragile planet, but we also manage to do our share to pollute the environment. We sure as heck do need California-type measures if we are to get ourselves out of this mess.

Taking advantage of every opportunity to reduce our impact on the environment is the short term. We must start planning for the long term too. Major reduction in fossil fuel use is absolutely essentially. Last year's Global Climate Change conference in Toronto called for a 20% reduction in carbon dioxide emissions within 15 years. I believe that a switch to biomass fuels is likely to play a major part in achieving that, and ultimately higher goals, but we don't have all the answers today. That means research and development, studying alternate fuels, developing environmentally sound, indeed sustainable, growing and production systems. I've heard lots of hype, especially from opponents of biomass fuel, and frankly a lot of the hype doesn't make much sense. Just as solar hot water heating and photovoltaic panels are ways of borrowing the sun's energy and making use of it in a sustainable way as that energy from the sun finds its way to the surface of the earth, so biomass fuels are also solar energy, making use of energy from the sun without causing the environmental damage that is so much associated with fossil fuels.

Let me sum up with a plug for the concept of sustainable development as described so eloquently by the Brundtland Commission. The World Commission on Environment and Development, established by the United Nations General Assembly, tells us, in its opening chapter, and I quote:

> From space, we see a small and fragile ball dominated not by human activity and edifice but by a pattern of clouds, oceans, greenery, and soils. Humanity's inability to fit its doings into that pattern is changing planetary systems fundamentally. Many such changes are accompanied by life-threatening hazards. This new reality, from which there is no escape, must be recognized - and managed.

Chapter One of the Brundtland Commission report is entitled "A Threatened Future". No other words can describe it more clearly. Fortunately, the final section of the same report is entitled "A Call for Action" and that's what I am making to you today and to the many other people with whom I have the pleasure of speaking

across Canada each month. That "Call for Action", that sustainable development, requires an integration of economic planning and environmental planning on a scale that only a few are beginning to understand. It makes no sense to talk about supply and demand without talking about the environment. It makes no sense to talk about energy needs without talking about the ability of the environment to accept those needs on a sustainable basis. It makes no sense to talk about gas or oil or electricity utilization without also planning for environmental improvements. In short, integration of the environment and economy is absolutely essential if we are to ensure the future of the planet. One thing we must do is fit our energy requirements into the "clouds, greenery and soils of this planet. Renewable fuels clearly have a role to play in ensuring the future iof our fragile planet.

October 18, 1989

CANADIAN EXPERIENCE WITH RENEWABLE FUELS

Ten years ago during the World Series, I loaded my wife into the car and we drove across the Prairies from Edmonton to Winnipeg; then down through Minnesota to Des Moines, Iowa; across Illinois to Chicago and then returned via Minneapolis and back to Winnipeg.

I can't remember who won the series, but it was one of the most important trips of my life because the size and scope of the bread basket of North America was spread out before us in all its gorgeous fall colors and the bounty of the grain harvest and the additional potential for growing even more biomass made an unforgettable impact.

Two years later in October 1981, we had acquired and converted an old whiskey plant and were trying to make ethanol. That's when idealism came to face with the realities of production, people training and marketing. We are celebrating our 8th Anniversary of the commencement of Gasohol in Manitoba with a big party at Minnedosa on October 27th and 28th.

The first couple of years were extremely satisfying for Mohawk in the marketplace. Memories of gasoline shortage

HAD NOT YET DIMMED AND CRUDE OIL PRICES WERE UP AT $30 TO $35 PER BARREL. MANITOBANS WERE ENTHUSIASTIC ABOUT GASOHOL AND SALES AT OUR STATIONS HAD INCREASED AS MUCH AS 50%. OUR ONLY PROBLEM WAS RELATED TO HIGHER PRODUCTION COSTS THAN WE HAD EXPECTED DUE TO UNFORESEEN PROBLEMS IN PROCESSING BARLEY AND A LOWER TOTAL THROUGHPUT THAN REQUIRED TO BRING COST OF PRODUCTION DOWN TO A PROFIT-MAKING LEVEL. WE PERSISTED TOWARD SOLVING OUR PRODUCTION PROBLEMS AND ARE STILL MAKING IMPROVEMENTS TODAY, BUT WE HAVE BEEN THROUGH SOME INTERESTING CYCLES IN THE MEANWHILE.

WE HAVE LEARNED HOW TO PROCESS CORN, WHEAT, HULL LESS BARLEY, SPROUTED RYE AND MANY OTHER DAMAGED GRAINS IN ADDITION TO BARLEY. FEEDSTOCK PRICES HAVE BEEN HIGH AND LOW IN VARIOUS YEARS AND THESE HAVE NOT ALWAYS COINCIDED WITH HIGHS AND LOWS IN GASOLINE PRICES, WHICH HAVE BEEN THE GOVERNING FACTOR IN DETERMINING THE SELLING PRICE OF ETHANOL. GASOLINE PRICES DROPPED BY ½ IN FEBRUARY 1986 AND WE HAD A DILEMMA. IN 1986 AND 1987 WE THOUGHT WE HAD A GOOD SOLUTION FOR THE ECONOMIC PROBLEM BY BLENDING LOW COST METHANOL WITH OUR HIGH COST ETHANOL AND MAKING AN EM GASOHOL BLEND. UNFORTUNATELY, THE OIL REFINERS JUST AT THIS TIME DECIDED TO INCREASE OCTANE IN THEIR GASOLINES BY ADDING BACK MORE BUTANE IN SUBSTITUTION FOR LEAD AND THE RESULTING HIGHER VAPOR PRESSURE CAUSED A SENSITIVITY BY THE MOTORING PUBLIC THAT MITIGATED AGAINST SUCCESS FOR OUR EM CAMPAIGN. WHEN SALES BEGAN TO FALL WE DROPPED EM.

In 1987 and 1988 there were a sufficient number of newer high performance engines in the marketplace that the demand for high octane premium gasolines began to amount to big numbers. Mohawk began, for the first time, to sell ethanol for one of its real values - octane enhancement. By adding ethanol to premium grade gasoline, we created a super high octane gasoline we called "Premium Plus", which we now offer at nearly all Mohawk stations in Western Canada. We receive testimonials regarding the performance of this fuel from many customers and from motor car companies as well. Sales of Premium Plus are going very well and have now become about 15% of Mohawk's product offering as compared to about 3% when we offered ordinary Premium.

It was not until 1989 that public awareness of the environmental problems caused by fossil fuels, such as gasoline and diesel fuel, came in to focus. The accumulation of carbon and hydro carbon compounds in the atmosphere are causing such severe problems in congested cities and threaten such massive global problems that all of us are wondering about our future.

Arising from the 1979 drive through the harvest areas of the northern parts of the great central plains, I have known that the correct source for our liquid fuel needs (or even our profligate desires) was based in

CONVERTING THE CORN STALKS OR THE WHEAT STRAW INTO ETHANOL. THE HUGE TONNAGE OF THIS MATERIAL BEING PLOWED UNDER OR BURNED IN GREAT ORANGE FIRES AGAINST THE PRAIRIE SKY WAS ENOUGH EVIDENCE OF ITS SURPLUS. IT WAS THE DISCOVERY THAT SEVERAL CANADIAN PROCESSES WERE BEING DEVELOPED FOR THE CONVERSION OF CELLULOSIC MATERIALS, (INCLUDING TREES) AND THAT THESE PROCESSES WERE NEARING THE ECONOMICALLY VIABLE STATE, THAT CONVINCED MOHAWK TO ACQUIRE AND OPERATE MINNEDOSA AS A PILOT PLANT. WE HAVE VIEWED CELLULOSICS AS OUR TARGET FEEDSTOCK FROM THE BEGINNING.

MAJOR EVENTS HAVE AFFECTED OUR THINKING DURING THE PAST FEW YEARS.

1. SURPLUS QUANTITIES OF CRUDE OIL AND GAOSLINE HAVE BEEN AVAILABLE MAINLY DUE TO THE CONSERVATION PRACTICES COMMENCED IN 1979 AND 1980. THIS REDUCED PUBLIC INTEREST IN ALTERNATE FUEL SUPPLY IN CANADA.

2. A BUMPER CROP IN 1987 COULD NOT FIND MARKET, WHICH AWAKENED SERIOUS INTEREST BY FARMERS IN DEVELOPING DEPENDABLE MARKETS FOR AGRICULTURAL PRODUCE - GRAIN OR ANYTHING.

3. A SEVERE DROUGHT IN 1988 CHANGED THE OUTLOOK TO THE OPPOSITE EXTREME IN WHICH GRAIN AS FEEDSTOCK FOR ETHANOL BECAME VERY HIGH-PRICED AND AGAIN REDUCED ENTHUSIASM

FOR AGRI PROJECTS. MORE SERIOUS STUDENTS OF THE ISSUES WERE ABLE TO LOOK AT THE LONGER TERM AND REALIZE THAT CANADIAN FARMERS MUST FIND MARKETS FOR THEIR PRODUCE THAT WILL NOT BE SUBJECT TO WILD SWINGS SUCH AS 1987 AND 1988.

4. THE MOST SIGNIFICANT OF ALL THE EVENTS OF THE LAST DECADE IS THE UNANIMOUS ACCEPTANCE OF THE FACT THAT WE MUST FIND OTHER SOURCES OF ENERGY THAN OIL AND COAL OR SUFFER THE OPTION OF REDUCING OUR ENERGY USE AND OUR STANDARD OF LIVING. IF WE DON'T DO EITHER, WE RISK UNKNOWN PERILS RESULTING FROM CLIMATE CHANGE AND DISRUPTION OF THE PATTERN OF LIFE ON OUR PLANET.

PAT FOODY OF TECHTROL LTD. PRESENTED A PAPER DATED SEPTEMBER 22, 1989, TITLED CO_2 ABSORPTION TO ACHIEVE GOVERNMENT ENVIRONMENTAL GOALS. ESSENTIALLY THIS PAPER HELPS US PERFORM THE CALCULATIONS THAT SHOW THAT WE COULD GROW ENOUGH POPLAR OR WILLOW TREES ON TREE FARMS ACROSS CANADA TO SUPPLY OUR GASOLINE REQUIREMENTS AND NOT STRAIN OUR FOOD SUPPLY IN THE LEAST. IT WOULD ONLY TAKE 8% OF OUR AGRICULTURAL LAND TO GROW TREES THAT WOULD YIELD 30 TONNES PER HECTARE. ANOTHER WAY OF LOOKING AT IT INDICATES THAT 50% OF THE LAND NOW DEDICATED TO GROWING OUR EXPORT GRAIN WOULD GROW ENOUGH TREES. THERE ARE INTERESTING

COMPARISONS OF THE FAVORABLE ECONOMICS, EMPLOYMENT AND REGIONAL ADVANTAGES THAT WOULD FLOW FROM AN ETHANOL FUEL SUPPLY SYSTEM RATHER THAN ARCTIC WELLS, HIBERNIA PLATFORMS OR TAR SANDS PLANTS. THE VERY MOST ATTRACTIVE ASPECT OF THE PAPER IS THAT WE CAN CONTINUE TO ENJOY OUR CARS, BENEFIT FROM TRUCKS AND TRAINS AND CONTINUE TO EXPAND OUR POPULATION. IN ADDITION, WITH ETHANOL GROWN FROM CELLULOSICS ALL AROUND THE EQUATOR, THE UNDERDEVELOPED COUNTRIES CAN LOOK FORWARD TO INCREASING ETHANOL FUEL SUPPLIES TO VAULT THEM INTO MODERN ENERGY DEPENDENT LIFE STYLES.

ETHANOL IS THE ONLY ENVIRONMENTALLY BENIGN AS WELL AS RENEWABLE FUEL SUITABLE FOR MANY INTERNAL COMBUSTION ENGINES. IT IS TRUE THAT SOLAR AND WIND ENERGY MUST BE EXPLOITED, FUEL CELLS MUST BE FURTHER DEVELOPED AND ELECTRICITY FROM MANY SOURCES SHOULD BE HARNESSED. IT MAY BE THAT WE CAN LEARN HOW TO HANDLE NUCLEAR ENERGY WITHOUT THE RISKS. BUT COMPARED TO ANY OF ACTION PLANS THAT ARE CURRENTLY BEING PROPOSED FOR ALTERNATE LIQUID FUELS OR GASEOUS FUELS OTHER THAN FOR VERY SHORT TERM STOP GAP IMPROVEMENTS IN TAIL PIPE EMISSIONS, ETHANOL IS FAR MORE ATTRACTIVE.

WIDESPREAD MANUFACTURE AND USE OF ETHANOL AS A BLEND COMPONENT OR IN NEAT FORM WILL DO MORE FOR CORRECTING THE CARBON BALANCE IN OUR ATMOSPHERE THAN ANY OTHER FUEL.

THERE ARE STILL SOME CONCERNS ABOUT THE COST OF ETHANOL, BUT THIS MAY BE THE POOREST ARGUMENT OF ALL. A LIVABLE PLANET IS A LOT MORE DESIRABLE THAN A CHEAP FUEL.

THE FINAL ARGUMENT FOR ETHANOL SHOULD BE THAT IT CAN BE MADE ANYWHERE IN CANADA - ANYWHERE IN THE WORLD IN SMALL QUANTITIES AND YOU CAN CARRY IT IN A PAIL.

LET'S USE NUCLEAR FOR SHIPS AND TRAINS; ELECTRICITY FOR DOMESTIC ENERGY, GASEOUS FUELS AND METHANOL WHERE WE HAVE THEM AVAILABLE, JET FUEL FOR OUR PLANES AND LET US KEEP ON DRIVING OUR CARS WITH ETHANOL IN A CLEAN AIR ENVIRONMENT.

RENEWABLE FUELS ARE PROVEN TECHNICALLY

Ethanol has a proven track record, internationally, as an automobile fuel. The fuel ethanol industry is well developed in the United States. In 1988 ethanol blend sales represented 8% of the total gasoline sales in the United States. More than 31 billion litres of ethanol gasoline blends — equivalent to the entire Canadian gasoline market — were sold in 42 states across the United States last year. Americans have driven over 700 billion miles on ethanol blended fuels since 1979.

The use of ethanol-blended gasoline has been actively encouraged by governments and environmentalists in the **United States** for a number of reasons including:

- improved air quality
- reduced dependence on imports of foreign oil
- concerns about environmental hazards associated with tanker movement of frontier and imported oil
- market opportunity for surplus agricultural crops.

Support for fuel ethanol was a key component in the "Clean Air" bill introduced by President Bush a few months ago.

Warranty coverage is provided for the use of properly blended ethanol-gasoline blends for all automobiles sold in North America. The General Motors Corporation has gone further in "endorsing" the use of oxygenated fuels, beginning with the 1990 model year, because of their beneficial effect on air quality.

Brazil is the world's leader in the use of ethanol as an automobile fuel. More than 8 billion litres of ethanol are made for fuel use each year. About 15 percent of vehicles with spark ignition engines (the type normally fuelled by gasoline) run on neat ethanol, and the rest use a blend of 20 percent ethanol in gasoline. Ethanol was introduced to reduce Brazil's dependence on expensive foreign oil, and provide an increased market for the domestic sugar producers. Beneficial effects on air quality have been an added bonus.

In **Canada** the industry is far smaller with only one company, Mohawk Oil Co. Ltd. producing and marketing fuel ethanol in Western Canada. Canadian experience with ethanol-blended gasoline amounts to about 3 billion miles. Ethanol-blended gasoline is currently marketed in five provinces and the Yukon territory. Four provincial governments currently offer tax incentives for the production and/or marketing of ethanol-blended gasolines. These incentives were implemented to encourage the development of an alternative fuels industry for varying reasons including energy diversity and stimulation of the agricultural economy. To date, federal government support for fuel ethanol development in Canada has been very limited relative to other countries — consisting of some financial support for the construction of a few smaller ethanol-manufacturing plants, and the funding of certain studies.

GASOLINE AND ENVIRONMENTAL CONCERNS

Lead

Tetraethyl lead has been used to raise the octane of vehicle fuels for years. Lead is known to be a health hazard, causing adverse learning and behavioural effects in children, and high blood pressure in adult males. Although lead has largely disappeared from U.S. gasoline, and will do so in Canada by 1991, many of the compounds used as replacements can also be hazardous from a health or environmental standpoint.

Hydrocarbons

Petroleum and gasoline consist of blends of hydrocarbons. Many of these are carcinogenic, such as the high-octane hydrocarbon, benzene. Hydrocarbons escape into the air during refilling, from gasoline tanks and carburetors during normal operation, and from engine exhaust. Transportation sources account for 30 to 50 percent of hydrocarbon emissions into the atmosphere.

Ozone

Ozone is formed in air when hydrocarbons and nitrogen oxide react in the presence of sunlight and heat. Ozone impairs respiratory function and destroys green plant tissue.

Carbon monoxide

This gas is colourless, odourless, and poisonous. Based on data from the United States, transportation sources account for over two thirds of all carbon monoxide emissions. Carbon monoxide is formed during the incomplete combustion of gasoline and other carbon fuels. Carbon monoxide has an adverse effect on the function of the cardiovascular system. Carbon monoxide has been identified as a serious air pollutant in many U.S. cities — several of which have mandated the use of "oxygenated" gasolines (for example, ethanol-blends) to reduce carbon monoxide emissions from cars.

Carbon dioxide

Carbon dioxide is a by-product of burning fuel and contributes to the greenhouse effect. All petroleum (hydrocarbon) fuels result in increased atmospheric carbon dioxide levels because they represent the combustion of fossilized carbon. Renewable fuels, such as ethanol, by contrast, mean no increase in atmospheric carbon dioxide levels because the carbon dioxide formed during engine combustion is balanced by that formed during the annual growth of green plants used to produce ethanol. In fact, because only about half of the mature weight of the crop plant is commonly used to produce ethanol (the rest is normally returned to the soil to form soil organic matter), renewable fuel technology can result in a net reduction in atmospheric carbon dioxide levels.

WHAT ALTERNATIVES ARE AVAILABLE?

- **to replace tetraethyl lead as an octane enhancer for gasoline.**
- **to extend Canada's dwindling domestic supply of light crude petroleum used to produce transportation fuels.**

MMT (Methylcyclopentadienyl manganese tricarbonyl) — widely used in Canada as an octane enhancer in lead-free gasoline but banned for this purpose in the United States because it increases the amount of hydrocarbons in automobile exhaust fumes. All MMT used in Canada is imported from the U.S.

Aromatic hydrocarbons — being used increasingly as octane enhancers even though they are often carcinogenic, or form carcinogens during engine combustion.

Oxygenates — compounds which contain oxygen in their molecular structure, such as alcohols and ethers, as compared to hydrocarbons, which contain only carbon and hydrogen. Many oxygenates serve as excellent octane enhancers when blended with gasoline.

Methanol — is an alcohol made from natural gas, which can be used directly as an automobile fuel (the engine then needs modifications for this purpose), or as a gasoline-blending compound. When methanol is blended with gasoline, a cosolvent, such as ethanol is required.

Ethanol — made from renewable biological feedstock, can be used directly as a fuel (such as commonly occurs in Brazil), or as an octane enhancing gasoline additive. Approximately 8% of all U.S. gasoline contains ethanol at a blending percentage of 10%. Five and ten percent blends of ethanol in gasoline are being marketed by Mohawk Oil in Canada. Ethanol, or ethanol/methanol-blended gasoline can be used in all gasoline-requiring automobiles, without engine modification.

Methyl tertiary butyl ether (MTBE) — is another oxygenate made from hydrocarbons which is being used in Canada and the U.S. as an octane-enhancer for gasoline.

Propane and natural gas — other hydrocarbons, used as automobile fuels in Canada (with the assistance of tax reductions or exemptions not available for ethanol and methanol). Modification is needed for automobiles to use these fuels. Both propane and natural gas come from fossil hydrocarbons and result in increased atmospheric carbon dioxide levels when combusted in automobile engines.

Foreign and frontier oil sources — utilization of these energy sources can be both environmentally dangerous and either expensive (frontier) or uncertain (foreign) as to both cost and reliability. Their combustion adds to atmospheric carbon dioxide levels.

Important attributes of
non petroleum vehicles relative to gasoline
Vehicles from a consumer perspective

	CNG Dual Fuel	CNG Dedicated	LNG Dedicated	Alcohol Multifuel	Alcohol	Hydrogen	Electric Vehicles
Fuel price	Much lower	Much lower	Much lower	Slightly more	About same	Much more	Varies
Vehicle price[a]	More	Slightly more	Slightly more	About same	About same	More	More[b]
Performance	Worse	Same	Slightly better	Same	Better	Same[c]	Much worse
Startability	Same	Better	Better	Worse	Worse	About Same[c]	Better
Luggage space	Much less	Less	Slightly less	Same	Same	Less	Much less
Driving range	Much less on CNG	Less	Less	Much less on alcohol	Less	Less	Much less

[a]Assumes large production volumes.

[b]Including batteries.

[c]For liquid hydrogen. If hydrogen is stored in hydrides, then performance would be slightly worse and cold start somewhat more difficult.

Ref: New Transportation Fuels. 1989. D. Sperling. University of California.
ISBN 0-520-06087-3.

FUEL ETHANOL AND FOOD PRODUCTION

Although ethanol can be made from a wide variety of biological materials, agricultural crops — and, particularly, grain — are likely to serve as a principal feed-stock because of their high productivity and their high concentrations of carbohydrates available for ethanol manufacture by fermentation.

Fortunately, extensive production of ethanol from grain will not detract from Canada's ability to both feed its own citizens and supply large quantities of high-quality grains to export markets.

Canada typically produces about 50 million tonnes of grain annually and exports over half of this. If all Canadian gasoline consumption (presently about 30-35 billion litres annually) had 10% ethanol, the resultant maximum grain requirement would be 8 million tonnes. Canada would remain a major grain exporter.

Mention should be made, also, of the fact that ethanol is (and will be) produced preferentially from lower value grains such as barley, corn and feed wheat. Higher quality "bread" wheats, which represent Canada's "ace" in world grain markets, would remain in ample supply for export sales, even with major expansion in ethanol manufacturing capabilities in Canada.

In practice only about 2/3 of each tonne of grain can be used to produce ethanol. The remaining by-product, which is high in protein, is used as livestock feed.

SUPPLY AND DISPOSITION OF CANADIAN GRAIN
(10 YEAR AVERAGE FIGURES 1978/79 TO 1987/88 IN THOUSANDS OF TONNES)
Ref. Canadian Grains Industry, Statistical Handbook, '88

	Supply		Disposition	
	production	imports	exports	feed/waste
Wheat	23 837	0	18 634	2 462
Barley	11 936	12	4 648	6 617
Corn	6 132	674	559	5 109
Rapeseed/Canola	3 059	6	1 575	309
Soybeans	906	271	127	71
Total	45 870	963	25 543	14 568

Canada is a major importer of high-protein animal feed ingredients with the value of imports typically being worth about $300,000,000 annually. The by-product resulting from ethanol production from Canadian grain would serve to displace this importation.

The high-protein by-product from ethanol manufacture is particularly well suited for the nutrition of ruminant animals such as cattle and sheep. The protein in this material is utilized more efficiently in ruminant nutrition than is the case with other high-protein feed ingredients such as soybean meal. The grain by-product from ethanol manufacture would be particularly advantageous in Canadian dairy and beef production and would improve the competitive position of producers of dairy farm commodities relative to their global counterparts. The manure from livestock can be used as a major source of fertility in grain crop production.

Fuel ethanol can also be made from high-cellulosic materials such as forestry wastes (sawdust, etc.) and agricultural crop residues. As the technology improves for ethanol production from these biological feed-stocks, these materials would be expected to serve as an increasingly important base for ethanol production in Canada. However, it will be important to ensure that excessive amounts of crop residue not be removed from farm land so as not to distort the vital role which these residues serve in building soil organic matter levels.

Although fuel ethanol makes sense for many reasons, its benefits for Canadian agriculture are also substantial. These benefits, in turn, could serve to improve farm income in Canada — thereby increasing the economic well-being of rural Canada.

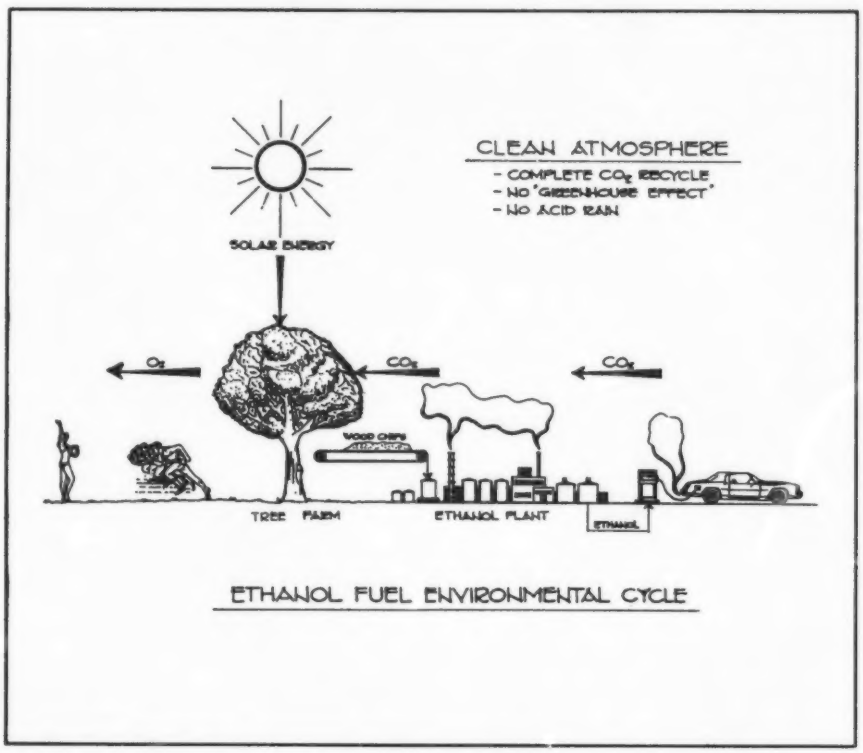
HOW DOES ETHANOL "CLEAR THE AIR"?

Carbon dioxide

Unlike virtually all other liquid fuels which are made from fossil hydrocarbons (petroleum, natural gas), ethanol is produced from renewable, biological feed-stocks, such as agricultural crops and forestry by-products. Although carbon dioxide is produced when ethanol is combusted in an automobile engine (just as it is when other fuels are burned), the carbon dioxide released into the atmosphere is recycled back into organic tissue during the growth of plants.

However, the benefit is even greater since only about half, or less, of the organic matter is actually removed from the farm fields. The rest is returned to the soil as organic matter. With modern "conservation" farming practices, this soil organic matter level will build up, representing a net loss in carbon dioxide from the atmosphere. An increase of only 1% in the soil organic matter level means an atmospheric loss of over 40 tonnes of carbon dioxide per hectare of farm land.

Hence, ethanol use in gasoline can actually mean a net loss in atmospheric carbon dioxide levels.



Courtesy Iogen Corporation

Carbon monoxide

Carbon monoxide is formed by the incomplete combustion of gasoline, and is produced, most readily, from hydrocarbon (i.e., fossil) fuels which contain no oxygen in their molecular structure. Because ethanol, and other "oxygenated" compounds, contain oxygen, they combust more completely in automobile engines —with the result being a substantial reduction in carbon monoxide emissions. Research results show that reductions range from 20 to 35%, depending on type of automobile, the automobile emission system used, and the atmospheric conditions in which the automobile operates.

Because of health concerns associated with carbon monoxide in air, several U.S. jurisdictions, including the entire state of Colorado, have mandated the use of oxygenated gasolines during the critical winter period when atmospheric carbon monoxide levels are highest. Mandatory use of oxygenated gasolines is being considered elsewhere, including New York City, to reduce carbon monoxide pollution.

Winter-time atmospheric carbon monoxide levels in downtown Toronto commonly exceed U.S. maximum tolerated levels by a wide margin. (Canadian air quality standards are not as stringent.) Carbon monoxide is also a notable air pollutant in Calgary, Edmonton and Vancouver.

EPA CARBON MONOXIDE AMBIENT AIR CONCENTRATION STANDARDS

ONE HOUR 35 ppm	EIGHT HOUR 9 ppm
(one exceedence/year/site)	(one exceedence/year/site)

In 1986, Denver, Colorado had 33 days over 9 ppm.

Other octane additives

Because of its high octane rating, the addition of ethanol to gasoline can permit the removal of lead, MMT, aromatic hydrocarbons and other dangerous high-octane additives commonly added to Canadian gasoline.

Ozone

Because of its effect in reducing exhaust emissions of hydrocarbons and carbon monoxide, ethanol addition to gasoline can mean a reduction in the ozone-formation potential associated with automobile exhaust fumes.

Ethanol has no significant effect, positive or negative, on emissions of **nitrogen oxides** — another common precursor of atmospheric ozone.

Although ethanol addition to gasoline can mean a potential increase in the "volatility" of gasoline, this potential is controlled by ensuring that all ethanol-blended gasoline sold in Canada meets the same volatility standards as are required for other types of gasoline.

Addition of ethanol to gasoline does mean that slightly greater amounts of aldehydes are formed during engine combustion, but the resulting concentrations are extremely small. And the aldehydes formed are effectively eliminated by the catalysts contained in the exhaust system of all modern cars. The Royal Society of Canada in a recent study termed the possibility of negative health effects caused by such aldehyde emissions as "remote".

WHAT'S NEEDED TO MAKE IT HAPPEN!

— A clear commitment by the Government of Canada to reduce air pollution problems associated with automobile exhaust emissions. This means reduced emissions of carbon monoxide, hydrocarbons and other ozone precursors. It also means measures to reduce the usage of fossil fuels, which lead to increased atmospheric carbon dioxide levels, and to encourage greater usage of ethanol made from renewable, biological feedstock, which results in carbon dioxide utilization.

— Adoption of U.S. prohibitions on the addition of MMT to gasoline — thereby reducing hydrocarbon emissions from automobiles.

— Mandating the use of oxygenated gasoline in urban centres where carbon monoxide levels exceed U.S. air quality standards. (Adoption of the same, more stringent standards in Canada.)

— Restrictions on the usage of cancer-causing aromatic hydrocarbons as octane-enhancing additives for gasoline.

— Financial incentives by the Government of Canada for the expanded use of fuel ethanol. These incentives could include tax reductions on ethanol-blended gasoline, such as are already provided for propane and compressed natural gas used as transportation fuels in Canada, or such as those offered for fuel ethanol usage in the United States.

ETHANOL AND THE CANADIAN ECONOMY

Critics of ethanol for use as a transportation fuel have emphasized its present production cost (about 40-45 cents per litre) relative to that of "refinery-gate" gasoline — about 20 to 24 cents per litre.

However such a perspective ignores:

1. The **high octane-blending value of ethanol** and its potential to replace environmentally hazardous compounds such as lead, MMT, and aromatic hydrocarbons currently being used widely as octane enhancers in Canadian gasoline. The octane level of gasoline can also be raised by the further refining of petroleum but this requires major capital expenditures, and a lower "yield" of gasoline per barrel of petroleum crude.

2. **Historic price patterns for crude petroleum** (the feed-stock for gasoline) and grain (a major feed-stock for ethanol production). For example, over the past 40 years, the real (inflation-corrected) price of Canadian grain has decreased by approximately 50% while that for crude oil — even at present "depressed" world prices — has about tripled. A continuation of this trend, plus the rapid pace of technological improvement in ethanol-production technology, will mean a continued improvement in the relative cost-of-production ratio between fuel ethanol and hydrocarbon-based gasoline.

3. **Canada's growing dependence on imported light crude oil** needed for gasoline and diesel fuel manufacture. The Government of Canada projects that by the mid 1990's, Canada will be importing about 500,000 barrels of light crude oil per day (by tankers) to meet transportation fuel needs — and this is even with the added supply to be created by new "mega-project" developments. This importation will cost about $5,000,000,000 annually at the present global crude oil price.

4. **The cost (financial and environmental) of mega-projects** for enhancing Canadian domestic supplies of light crude oil. Fuel ethanol compares favourably, in both capital and operating costs of production, to Hibernia and "tar sand" projects which are being planned with major governmental assistance.

5. The **abundant supply of Canadian grain** available for fuel ethanol production and its endlessly renewable nature. If usage of fuel ethanol were to increase so that ethanol was present in all Canadian gasoline at a 10% concentration, Canada would still remain one of the world's major grain-exporting countries.
   And the potential exists to make fuel ethanol from a wide range of other biological materials such as forestry and municipal waste, etc., available in every Canadian province.

6. The **by-product of ethanol production from grain** which is a high-protein livestock feed ingredient, and which could be used to replace Canadian imports of high-protein feeds, worth about $300,000,000 annually.

7. The **effect of ethanol additions to gasoline on environmental quality** including the potential to reduce carbon dioxide emissions to the atmosphere.
   What "economical" credit should be given to the major benefit that fuel ethanol represents relative to environmental quality?
   And should Canadian transportation fuel policy be dictated simply by short-term oil industry economics?

FUEL TERMINOLOGY AND TECHNOLOGY

Gasoline standards

The regulation of gasoline quality is a provincial responsibility in Canada. National specifications have been produced by the Canadian General Standards Board (CGSB) of the Government of Canada, and many provinces (including Ontario) require that all gasoline meet CGSB standards. Gasoline marketers generally ensure that gasoline sold in other provinces also meets these standards. All ethanol-blended gasoline sold in Canada meets CGSB specifications — including specifications regarding volatility levels.

Automobile function

All automobiles sold in North America are designed to operate with ethanol-blended gasoline, at a concentration of up to 10% ethanol, without modification. (This contrasts to propane and compressed natural gas — CNG — usage where extensive modification is required).

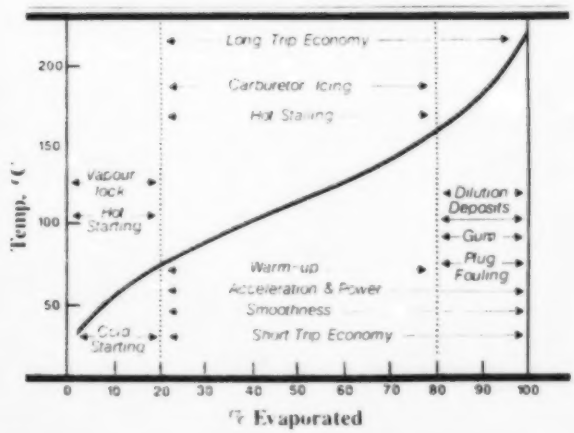
If the ethanol concentration increases well above 10%, for example to 20% ethanol or even "neat" (i.e., near 100%) ethanol as are used in Brazil, a higher engine compression ratio is desirable to take advantage of the **higher octane rating** of ethanol compared to normal gasoline mixtures. Higher compression ratios can, in turn, mean greater pressure on engine bearings and engines must be designed for this. (Racing cars commonly use ethanol, or other alcohols, as the principal source of "high octane" fuel.) However, this is not a factor with the 5% or 10%-ethanol blends sold in North America.

Ethanol generally burns at a slightly cooler temperature and more cleanly than normal gasoline. This can mean longer spark-plug life in most engines.

Although ethanol, theoretically, contains less "caloric" energy than gasoline and should, therefore, mean poorer fuel efficiency, research results with 10% ethanol-blended gasoline have shown that actual fuel efficiency is essentially identical to that of regular (ethanol-free) gasoline. The discrepancy can be explained by the greater efficiency with which ethanol is combusted during engine ignition.

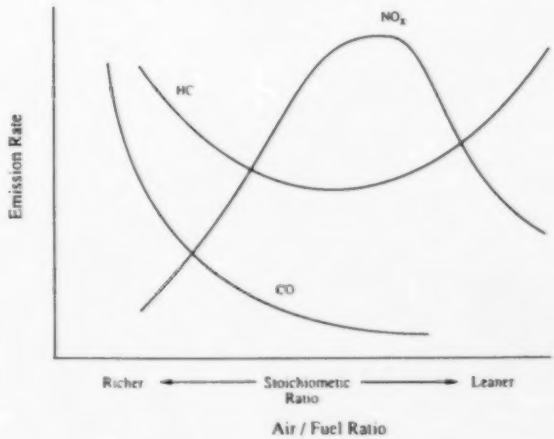
Octane — a measure of how well a fuel resists premature combustion, or knocking. Gasoline with too low an octane rating converts fuel to heat, rather than power, making for a less efficient fuel, loss of mileage and engine life reduction. Two different numbers are often reported, the Research Octane Number (RON), and the Motor Octane Number (MON). Isooctane (a flammable, colourless, liquid hydrocarbon used for comparing ignition characteristics) has a value of 100 for both RON and MON. When ethanol and methanol are blended at the five- and ten-percent level with gasoline, the octane number increases more than would be expected — there is "octane improvement".

Effects of volatility on engine performance



Ref. Discussion paper on oxygenated gasolines 1986. Energy, Mines and Resources Canada.

Emissions as function of air-fuel ratio



Ref: New Transportation Fuels. 1989. D. Sperling. University of California. ISBN 0-520-06087-3.

Volatility — a measure of the tendency to evaporate. To burn properly in an internal combustion engine, the fuel must be well vapourized. The higher the volatility of a fuel, the greater the level of evaporative emissions. If volatility is too low, there can be starting problems at low outside temperatures; if top high, there can be premature vapourization, particularly in hot weather, causing engine stalling. The Reid Vapour Pressure (RVP) is the measure of the fuel's vapour pressure at 37.8 degrees C, and is important for startability, vapour lock, and evaporative emission assessment.

Chemical properties

Here are some property comparisons:

Property	Methanol	Ethanol	Unleaded regular gasoline
Density (g/ml)	0.79	0.78	0.69-0.80
Boiling point °C	65.0	78.5	27-225
Flashpoint °C	11.1	12.8	-43
RON	112	111	91-93
MON	91	92	82-84
RVP	32	17	48-103

The alcohols are pure compounds and have specific values for technical analytical determinations. Commercial gasoline is made up of a mixture of hydrocarbons and depending on the hydrocarbons in the fuel, exhibit a range of values.

VOC — volatile organic compounds which mix with nitrogen oxides in the presence of sunlight and heat to produce ozone,

— evaporates off gasoline before 'burning'
— comes out tailpipes

Particulates — create smoke

Cetane number — a measure of self-ignitability

Selected properties

	Methanol	Ethanol	Gasoline	CNG
Density (lb/gal)	6.63	6.61	6.20	1.08
Energy content (Btu/gal)	56 560	75 670	115 400	19 760
(kg cal/L)	3 751	5 018	7 653	1 310
Vapour pressure *	0.32	0.21	0.6-0.84	—
Water solubility	infinite	infinite	nil	—
Air/fuel ratio	6.4	9.0	14.6	—

* at 33 °C (kg/cm²)

Ref: New Transportation Fuels. 1989. D. Sperling. University of California Press, Berkeley, California. ISBN 0-520-06087-3.